National Environmental Monitoring Standards

Erodible Land and Mitigation

Measurement of erodible land and vegetation-based mitigation

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Change register

Version Number	Revision Date	Section	Topic	Revision Summary
1.0.0	February 2026			Initial release

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The National Environmental Monitoring Standards

The National Environmental Monitoring Standards (NEMS), and associated codes of practice, Glossary, and National Quality Code Schema can be found at www.nems.org.nz.

Development

The strategy that led to the development of these Standards and associated documents was established by Jeff Watson (Chair) and Rob Christie (Project Director) of the initial National Environmental Monitoring Standards (NEMS) Steering Group, in 2014.

The NEMS initiative is supported by the Environmental Data Special Interest Group (ED SIG) (formerly the Local Authority Environmental Monitoring Group (LAEMG)), who contribute members to the NEMS Steering Group.

Implementation of the strategy is overseen by the NEMS Steering Group, which currently comprises Glenn Ellery (Chair), Jeff Watson (Technical Advisor), Phillip Downes, Rachel Herbert, Jon Marks, Charles Pearson, Jochen Schmidt, Clare Barton, Abi Loughnan, Sonja Miller, and Raelene Mercer (Project Manager).

The NEMS Steering Group directs preparation of NEMS documents on authority from the Chief Executives of the regional and unitary councils and the Ministry for the Environment (MfE).

The development of these documents involves consultation with regional and unitary councils across New Zealand, major electricity generation industry representatives, research institutes, and organisations providing supporting services such as laboratory processing. These agencies together are responsible for the majority of environmental monitoring in New Zealand.

This document has been prepared by Reece Hill of Landsystems (lead writer), with assistance and input from the NEMS Working Group and other contributors. The NEMS was initiated and funded by the Ministry for the Environment, with valuable input from its staff including Nina Koele, Deborah Burgess, and Fiona Curran-Cournane. Additional input was provided by: Jeff Watson (NEMS Technical Advisor), Malcolm Todd and Andrew Steffert of Horizons Regional Council; Kurt Barichievy and Ashton Eaves of Hawke's Bay Regional Council; Bryce McLoughlin of Gisborne District Council; John Ballinger of Northland Regional Council; Matt Oliver of Marlborough District Council; and Victoria Fox of Taranaki Regional Council. Input from Ministry for Primary Industries staff, including Malcolm Penn and Louise Askin, is gratefully acknowledged, as are valuable review comments from other Ministry for Primary Industries staff external to the Working Group. The comments provided by the external reviewer, Andrew Burton, and final proofreading by Laura Keenan are gratefully acknowledged.

Implementation

Stationarity

NEMS Standards are intended for long-term monitoring programmes. Stationarity of record, whereby changes to methods and instruments do not introduce bias over the lifetime of the record, is an essential property (see also NEMS Glossary), without which a record cannot be confidently analysed for temporal trends.

Because the methods of collecting and processing environmental data do change over time, the Standards include provisions for identifying and mitigating potential loss of stationarity.

Data fit for purpose

To facilitate data sharing, the NEMS Steering Group recommend that NEMS Standards are adopted throughout New Zealand and all data collected be processed and quality coded in accordance with the methodologies described in the Standards.

The quality code is determined from the Standard adopted and applied at the time of data acquisition. The degree of rigour with which requirements of the Standards are applied may depend on the quality of data sought. The highest quality code (QC 600) may be assigned to data that meet the stated requirements for good data.

Data of lesser quality are accommodated but are assigned a lower quality code (i.e. less than QC 600). They may be fit for the current intended monitoring purpose but restricted in their use for a range of other current and future purposes.

Measured data coded as QC 500 (fair), or QC 400 (compromised) may be the best practicably achievable due to site limitations and/or transient lapses in data quality.

Health and safety

When implementing the Standards, current legislation relating to health and safety in New Zealand and subsequent amendments shall be complied with.

NEMS Codes of Practice (COP) provide additional guidance on health and safety issues and structural design. Use only the most recent published version of any NEMS COP.

Limitations

It is assumed that, as a minimum, the reader of these documents has an understanding of environmental monitoring and data processing techniques, and some competency in their application.

The documents do not relieve the user (or a person on whose behalf they are used) of any obligation or duty that might arise under any legislation, and any regulations and rules under those Acts, covering the activities to which these documents have been or are to be applied.

Instructions for manufacturer-specific instrumentation and methodologies are not included in NEMS documents.

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Funding

Core funding of the NEMS project at the time that this document was developed was provided by the Ministry for the Environment with in-kind contributions from New Zealand regional councils and unitary authorities.

A full list of those who have contributed funding and time to the NEMS project is available at www.nems.org.

Review

This document will be assessed for review within one year of its initial release and thereafter will be assessed for review approximately once every two years. Document status and proposed review dates can be found at www.nems.org.nz.

Feedback

If you wish to provide feedback regarding this version of the document, please provide it to https://www.nems.org.nz/feedback/.

About This Standard

Introduction

The erosion of anthropogenically modified land contributes to topsoil loss and the sedimentation of waterways, compromising both land use and the environment in Aotearoa New Zealand. Erosion is a widespread and longstanding issue in New Zealand, with the loss of soil considered irreversible as topsoil can take 100s of years to develop under natural conditions (Doran et al., 1996). Erosion rates have been accelerated in landscapes modified by human activity, with rates under pasture identified as being an order of magnitude greater than those under indigenous forest (Wilmshurst, 1997). This problem is expected to be further exacerbated by climate change, with increasing storm frequency and intensity contributing to projected increases in soil loss through erosion.

To mitigate this, soil conservation activities are used to stabilise erodible land, and standardised monitoring is essential for effective management over time. The national Highly Erodible Land (HEL) model and resulting spatial layer (the HEL layer) provide a baseline of land at risk of mass-movement soil erosion—such as landslide, earthflow, and gully erosion—where there is no protective woody vegetation (Dymond et al., 2006). The HEL model, however, does not factor in smaller-scale conservation measures, such as space-planted trees, because a national dataset of this information does not currently exist (Dymond and Shepherd, 2023). While the Ministry for Primary Industries (MPI) holds a national spatial database of MPI-funded mitigations, this does not include private- or council-funded work or passive reversions. Councils report their MPI-funded work to this dataset using common templates.

The HEL layer complements existing national frameworks for assessing land and erosion risk. The HEL layer focuses on identifying areas of high erosion risk and the potential for mitigation through vegetative cover, whereas the Land Use Capability (LUC) system, which is inherently embedded into the HEL layer (Dymond and Shepherd, 2023), assesses the physical capability of land to sustain productive use (Lynn et al., 2009). The Erosion Susceptibility Classification (ESC) (Basher and Barringer, 2017), while related, is a more targeted framework developed to manage erosion risk from plantation forestry activities under the National Environmental Standards for Commercial Forestry. ESC zones (green to red) are designed around operational forestry activities such as harvesting, roading, and earthworks, whereas the HEL layer provides a broader representation of erosion risk and mitigation potential across all land uses. As a result, areas mapped as HEL are expected to correspond broadly with high-risk ESC zones (orange and red), although HEL captures a wider range of erosion processes and management responses.

The HEL layer is useful for a variety of applications, including the prioritisation of farm, catchment, and regional soil conservation plans, as well as setting targets for the reduction of erodible land. Dymond and Shepherd (2023) recommended that maps of soil conservation actions be included in the HEL model in the future. While many regional councils already monitor these activities, they do so in a non-standardised way that hinders data aggregation for national reporting. This National Environmental Monitoring Standard addresses the need for standardised data by providing regional councils and territorial authorities (regional authorities) with a methodology to collect and validate more detailed, finer-scale data on specific erosion types and mitigations to improve the national baseline dataset. The Standard specifies how local or regional data can be used to modify the HEL model's components, namely the fundamental HEL layer[1] and protective land cover data[2].

The Standard provides methods for measuring erodible land irrespective of land cover or stabilisation mitigations, the extent of land with protective cover, and land that remains unprotected and highly erodible. This Standard also includes requirements for data validation, assessing mitigation quality and, optionally, for recording mitigation costs, which is essential information for measuring the success of protection measures and estimating the resources required. Regionally collected data are at a finer scale than data in the HEL model and have the potential to contribute to more accurate regional and national measurements of highly erodible land, making the standardisation of these data critical. This document sets out the process by which regional authorities and other agencies shall collect and record standardised data and report on erodible land and stabilisation mitigations at a regional or national scale.

Objective

The objective of this Standard is to ensure that the measurement data of erodible land and stabilisation mitigations, including their extent, is quality assured and preserved in a verifiable, consistent, and documented manner to a known standard over time throughout New Zealand.

Scope

This Standard focuses on the measurement of erodible land at regional and national scales. The specific areas of interest are erodible land and the presence or absence of vegetation cover or vegetation-based mitigations that protect erodible land.

The Standard generally assumes that a closed canopy of trees will protect the site from accelerated erosion. The composition of understorey tiers (where they may be present) is not considered when determining vegetated cover under this Standard.

Erodible land, land cover and stabilisation mitigation data are assigned a level of confidence, based on whether the data have been validated. The level of confidence applies to the polygon and not specifically to the spatial accuracy (i.e. the polygon boundaries). Spatial accuracy is assumed to be at least at the resolution of the New Zealand HEL model layer.

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[1] Referred to as the 'Highly Erodible Land fundamental layer' in Dymond and Shepherd (2023).
[2] Either the Land Cover Database (LCDB) or the Woody layer described in Dymond and Shepherd (2023).

Exclusions

This Standard does not cover:

- erosion types other than the mass movement (soil slip[3], earthflow and slump) and fluvial erosion (gully and tunnel) defined in this Standard[4],
- the design of a monitoring network for erodible land, land cover and mitigation extent,
- measuring and reporting on mitigations that are non-vegetation based,
- measuring and reporting on erodible land, land cover and mitigations at sub-regional scales,
- erosion triggered specifically by mechanical land disturbance (e.g. track construction) which is managed under the National Environmental Standard for Commercial Forestry.

Terms, definitions and symbols

The NEMS Working Group decided to list (below) the Terms, Definitions and Symbols in this first version of this Standard for the benefit of new users. These Terms, Definitions and Symbols will be removed in subsequent versions of this Standard and will then only be found in the NEMS *Glossary* available at www.nems.org.nz.

Where possible, the Terms, Definitions and Symbols have been aligned with those in Dymond & Shepherd (2023).

Accelerated erosion – erosion induced by human activities; in this NEMS it mainly refers to erosion initiated following forest clearance in hill country.

Adequate protective vegetation – vegetative cover that provides protective value—a level of cover that is sufficient and extensive enough to achieve stability against all forms of soil erosion. The essential criterion is that vegetation – planted or reverting – has protective value, not that it be woody.

Afforestation – the establishment of a forest or stand of trees in an area where there was no tree cover.

DEM (Digital Elevation Model) – a raster database of elevations.

Earthflow erosion – slow movement of soil and associated regolith, usually along basal and marginal shear planes, with internal deformation of the moving mass. The original vegetated surface is characteristically hummocky and may contain numerous tension cracks. Movement rates vary from <0.5 m/yr to >25 m/yr.

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[3] Earth slips are included but are treated as for soil slip.
[4] Although erosion types other than the mass movement are outside the scope of this Standard, their exclusion does not necessarily diminish their significance regarding sediment production.

Erodible land – land identified as being at risk of mass movement or fluvial erosion based on physical factors, irrespective of current land cover or stabilization mitigations. See **Local erodible land data**.

Erosion Susceptibility Classification (ESC) – the system used in New Zealand to classify land vulnerability to erosion and regulate plantation forestry activities.

Erosion terrain – a reclassification of the New Zealand Land Resource Inventory Land Use Capability units into terrains with similar dominant soil erosion processes and severities.

Exotic continuous-cover forest – a forest that is deliberately established for commercial purposes, being at least 1 ha of continuous forest cover of exotic forest species that has been planted and will not be harvested or replanted, or is intended to be used for low-intensity harvesting.

Exotic plantation forest – a forest that is deliberately established for commercial purposes, being at least 1 ha of continuous forest cover of exotic forest species that has been planted and will be harvested or replanted.

Farm plan – a spatial plan of soil conservation actions designed to reduce soil erosion on a farm, such as retirement of steep to very steep slopes, space planting of poplars on moderately steep slopes, afforestation of earthflows and gullies, and/or paired planting of poplars or willows on stream banks. Farm plan is used in this Standard in place of other similar terms (e.g. Whole farm plan, Soil conservation farm plan, Works plan, Conservation action map).

Fluvial erosion – the removal of material by channelised running water.

Full establishment – the stage where a mitigation measure has reached its intended functional maturity and provides structural reinforcement to the soil and regolith. This is generally achieved 10–15 years after implementation.

Fully effective – the state at which a mitigation measure has reached its intended design strength and provides the maximum theoretical reduction in sediment yield for that erosion terrain.

Fundamental erodible land – land that is classed as erodible without considering the presence of protective woody vegetation, including land that would be erodible if trees were removed, as defined by the fundamental HEL layer in the Highly Erodible Land model.

Fundamental highly erodible land layer (fundamental HEL layer) – national baseline dataset of land at high risk of mass movement erosion assuming no protective woody vegetation cover. Used in the national HEL model for deriving the HEL layer.

Gullies – large, permanent landform features, >60 cm deep and >30 cm wide, formed by the removal of soil, regolith or rock by fluvial incision. Initially formed through the channelised flow of water, these features involve the headward and sideward migration of the channel.

HEL layer – the national Highly Erodible Land spatial dataset derived from the high erodible land (HEL) model.

Highly erodible land (HEL) – land with no protective woody vegetation at high risk of soil mass-movement erosion (soil slip, earthflow, or gully).

Hill Country Erosion Programme (HCEP) – the Ministry for Primary Industries' Hill Country Erosion Programme – a partnership between central government and regional/unitary councils.

Implementation – the physical act of applying a mitigation measure to the land. This includes the physical planting of trees, the construction of stock-proof fencing for retirement, or the formal commencement of a reversion process.

Independent validation – validation of data undertaken or overseen by an **SCP** who was not the original creator or provider of the works or data.

Initial establishment – the stage, typically one year after planting, where a plant has successfully survived its first full climatic cycle and is confirmed to have taken root.

Indigenous planted forest – planted forest consisting of New Zealand indigenous tree species.

In-field plot data – quantitative data that have been collected in the field using standardised, repeatable, plot-based methods.

Land cover – the type of vegetation covering land (e.g. forest, pasture).

Land cover class – the classification classes within the Land Cover Database (LCDB) that describe land cover. Land cover classes are mutually exclusive and collectively sum to 100% of the surface area of New Zealand. First-order classes are based on the physiognomy of the land cover (e.g. forest), with lower order divisions providing further information based on other characteristics such as phenology (e.g. evergreen) and floristic composition (e.g. broadleaved).

Landslide – a generic term for the movement of a mass of rock, earth or debris down a slope, under the influence of gravity. In the broadest sense soil slip, debris avalanche, debris flow, rock fall, earthflow, and slump are all types of landslide.

Land Use Capability (LUC) – a systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production. Capability is used in the sense of suitability and versatility for productive use or uses after taking into account the physical limitations of the land. See **LUC Handbook**.

LCDB (Land Cover Database / New Zealand Land Cover Database) – a multi-temporal, thematic, and hierarchical classification of New Zealand's land cover that is periodically updated. The latest version of the LCDB and associated documents are found in the Land Resource Information Systems (LRIS) Portal (IRIS.scinfo.org.nz/). Land cover is classified into **land cover classes**.

LiDAR – a remote sensing technology that analyses light reflected from a laser-illuminated target to measure distance. Capable of producing high-resolution maps and 3-D images from which profiles and sections can be extracted.

Local erodible land data – high-resolution spatial data collected at a sub-regional scale that identifies erodible land to refine or replace the national fundamental HEL layer.

LUC Handbook – Land Use Capability Survey Handbook **-** a New Zealand handbook for the classification of land 3rd Edition.

LUC Unit (Lynn et al., 2009) – The most detailed component of the LUC classification. LUC Units group together areas where similar land inventories have been mapped, which require the same kind of management, the same kind and intensity of conservation treatment, and are suitable for the same kind of crops, pasture or forestry species, with similar potential yields.

Mass movement – soil erosion processes involving failure at depth (> 0.5 m). It encompasses a wide range of erosion types where material moves down slope as a more-or-less coherent mass under the influence of gravity. Includes the erosion types: soil slip, earthflow, slump, rockfall, debris avalanche and debris flow.

Metadata – structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource (data about data). For the purposes of this Standard, metadata shall include the date of capture, the source of the data, and the **SCP** responsible for validation.

Natural indigenous forest – indigenous forest that has not been planted, usually developing naturally following the retirement of land from production or reversion. See **Retirement** and **Reversion**.

New Zealand Land Resource Inventory (NZLRI) – a national spatial database providing an inventory of five physical land factors—rock type, soil, slope, erosion, and vegetation—which is used to create the Land Use Capability (LUC) rating for land across New Zealand.

Pixel – the smallest discrete component of a raster image or grid. In the context of the HEL layer, it represents the specific resolution (e.g. 15 m x 15 m) at which slope and rock type are modelled. See **Raster**.

Polygon – used in a general sense to define a unique spatial area in a GIS layer such as the HEL layer or local spatial data. Where required for clarity, the specific data name may precede the polygon term (e.g. LCDB polygon).

Protective woody vegetation – vegetation with woody stems and branches that typically possesses woody roots capable of strengthening soils at the soil/regolith interface. In the HEL model, this includes planted and reverting woody species that significantly reduce the risk of mass movement erosion compared to pasture or non-woody cover. See **Adequate protective vegetation**.

Raster – a data structure consisting of a grid of cells (or pixels) where each cell contains a value representing information.

Retirement – the retirement of land from productive use (usually involving the exclusion of stock by fencing). This can include reversion to woody indigenous vegetation or planting of indigenous vegetation. See **Indigenous planted forest** and **Natural indigenous forest**.

Reversion – the retirement of productive land (usually involving the exclusion of stock by fencing) to allow the re-establishment of indigenous vegetation, which may eventually develop into natural indigenous forest. See **Natural indigenous forest**.

Soil slip – a type of rapid mass movement that involves the failure of a shallow surface layer of soil and vegetation, leaving a slip surface and a debris tail. Movement is initially by sliding or a combination of sliding and flowing, typically resulting in a failure surface <1 m deep that is planar and parallel to the ground surface. For the purposes of this Standard, this term includes features locally referred to as earth slips.

Slope threshold – the slope angle that, when exceeded, indicates an increased risk of landsliding, particularly in the absence of protective woody vegetation, with its specific value varying based on the underlying geology and soil characteristics. Slope thresholds used in the HEL are provided in Dymond and Shepherd (2023).

Space-planted trees – trees (usually poplars) planted at spaced intervals to increase the strength of soil. Spacings vary depending on regional differences in climate, erosion type and severity, and the species used. Also referred to as pole-planted trees.

Stabilisation mitigation – vegetation-based soil conservation mitigations including space-planted trees, afforestation, retirement and reversion.

Suitably competent person (SCP) – a person with the appropriate skills and experience to undertake an assessment or supervise others to undertake an assessment. The qualifications of the **SCP** will vary depending on the skillset required for the specific assessment. Appropriate skills and experience may include a mix of formal tertiary qualifications in a suitable field and/or considerable and current experience of greater than three years. Certifications and approved competencies such as the Australian *Registered Soil Practitioner – Erosion and Sediment Control Accreditation*[5] and *Suitably Competent Mapper for the National Environmental Standards for Plantation Forestry Erosion Susceptible Classification*[6] may provide more certainty that the **SCP** has the appropriate skills and experience to undertake an assessment.

Tunnel gully erosion – erosion initiated by the subsurface concentration and flow of water, resulting in eluviation and scouring and the formation of narrow conduits, tunnels or pipes. Soluble, dispersive or low-strength material is removed, ultimately resulting in collapses, visible either as holes in the land surface or as gullies when sufficient collapses coalesce to form continuous linear features.

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[5] https://www.soilscienceaustralia.org.au/rsp/erosion-and-sediment-control-accreditation
[6] https://www.mpi.govt.nz/dmsdocument/28542/direct/

Validated data – is the term used in this Standard for local data that has been checked and confirmed by a **SCP** who was independent of the original data collection or mapping. See **SCP**.

Vector – a data structure used to represent geographic features as points, lines, or polygons.

Normative references

This code of practice shall be read in conjunction with the following references:

- NEMS *Glossary – Terms, Definitions and Symbols*
- NEMS *National Quality Code Schema*

The Standard – Erodible Land and Mitigation

Requirements and recommendations for the application of this Standard are summarised in the following tables:

- Minimum requirements for the application of all Standards.
- Requirements for data irrespective of quality.
- Additional requirements for data of good quality.
- Other requirements, guidelines, and recommendations.

Data that are collected, processed, and archived to meet requirements of the first three tables, in a verifiable and consistent manner, can be assigned the highest quality code (QC 600). When these requirements are not met, a lower quality code is assigned, deduced from the quality coding flow chart for highly erodible land and mitigation data. If requirements of the first table are not met the data cannot claim to be in accordance with NEMS and cannot be assigned a quality code.

Quality assurance requirements ensure the measurement system is robust so that the impact on data quality of unexpected circumstances or unanticipated combinations of factors is minimised. Their influence on data quality is therefore consequential and usually assessed during data processing, which is outside the scope of this document.

Additional requirements are required to enhance data quality and are mandatory for quality coding assigned to the data.

Other guidelines and recommended practices are those considered relatively easy to implement to enhance data quality but are not mandatory and do not alter quality code assigned to the data.

Minimum requirements for the application of all Standards

Table 1 – Minimum requirements for the application of all Standards.

Health and safety	Scope	All current legislation, including relevant amendments, shall be complied with.
Stationarity	Implementation Attribute tables (4)	• Maintained wherever possible. • Documented in metadata if change occurs or is likely to occur.
Units of measurement		Metric system to two decimal places. • Land area in hectares (ha). • Percentage cover (%).
Dating changes and updates *(Annex B)*		• Date reference of each version of database to follow that released with relevant version of the HEL layer. • Local data polygons to be date stamped using the dd/mm/yyyy format. • Validation of polygons to be date stamped using the dd/mm/yyyy format. • Mitigation quality assessment of polygons to be date stamped using the dd/mm/yyyy format.
Metadata *(Annex B)*	Scope	Permanently archived and discoverable.
	Identification of Standards	Standards and versions applied shall be tracked over time in time-stamped Stationarity Comments.
	Identification of data	All data shall be identified by a minimum of: • the variable's name and units (as defined in this Standard), and • date and time of the version update and any polygon validation.
	Quality coding	All data shall be quality coded using the Quality Code Schema set out in this Standard, as adapted from the NEMS *National Quality Code Schema*.
Archiving *(Annex B)*	Original and final records	Store, retain indefinitely, preferably electronically and back up regularly:

		• Original copy of HEL layer as released. • Local data, including any updates to polygons and relevant quality coding. • Additional data used for validation and mitigation quality assessments (e.g. regional models, LiDAR or other remotely sensed layers, aerial imagery). • All required metadata (including all calibration, validation, verification and editing information). • Additional time series and/or metadata used and/or generated during data processing.

Requirements for data irrespective of quality

Table 2 – Requirements for data irrespective of quality.

Application *(Annex B)*	Scope		Classes assigned to be dominant (>50% cover) within polygons
	Resolution		Mapping may be done at a higher resolution but must be able to be resolved to 1 ha for the backward correlation with previous data.
	Mapped area		Polygons defined by the boundaries embedded within the national HEL layer or local data.
GIS procedures *(Annex B)*	Attributes		Polygons must use attribute fields and values provided in this Standard.
	Polygon quality		GIS procedures must adhere to those inherent within this Standard.
Classification *(Sections 2 and 3, and Annex B)*	Fundamental erodible land classes	Erodible land classes	Labelling of erodible land classes must adhere to those in the HEL model and inherent within this Standard to retain ability to revise earlier versions if a new scheme emerges.
		Erosion types and severity	Labelling of erosion types and severity must adhere to those inherent within this Standard to retain ability to revise earlier versions if a new scheme emerges.
	Land cover and	Land cover classes	Labelling of land cover classes must adhere to those inherent within this Standard to retain

	mitigation classes		ability to revise earlier versions if a new scheme emerges.
		Woody layer classes	Labelling of woody layer classes must adhere to those inherent within this Standard to retain ability to revise earlier versions if a new scheme emerges.
		Mitigation classes	Labelling of mitigation classes must adhere to those inherent within this Standard to retain ability to revise earlier versions if a new scheme emerges.

Additional requirements for data of good quality

As a means of achieving QC 500, QC 550 or QC 600 under this Standard, the following requirements apply in addition to the requirements for the application of all Standards and the requirements for data irrespective of quality:

Table 3 – Additional requirements for data of good quality.

Data validation (level of certainty) *(Section 4.2)*	Erodible land classes	Data validation	Data validation using accepted methods to achieve QC 500.
	Land cover	Data validation	Data validation using accepted methods to achieve QC 500.
	Mitigations	Data validation	Data validation using accepted methods to achieve QC 500.
Mitigation quality *(Section 4.3)*	Mitigations	Mitigation appropriateness and mitigation effectiveness	Assessed mitigation appropriateness and effectiveness using accepted methods to achieve QC 600.

Other guidelines and recommended practices

The following table summarises other guidelines and recommended practices that are optional and not required for QC 600 but if implemented will enhance data quality.

Table 4 – Other requirements for data of good quality.

Other guidelines and recommended practices *(Section 5.1)*	Mitigations	Cost of mitigations	Area-apportioned costs for individual polygons.

Quality coding flowchart

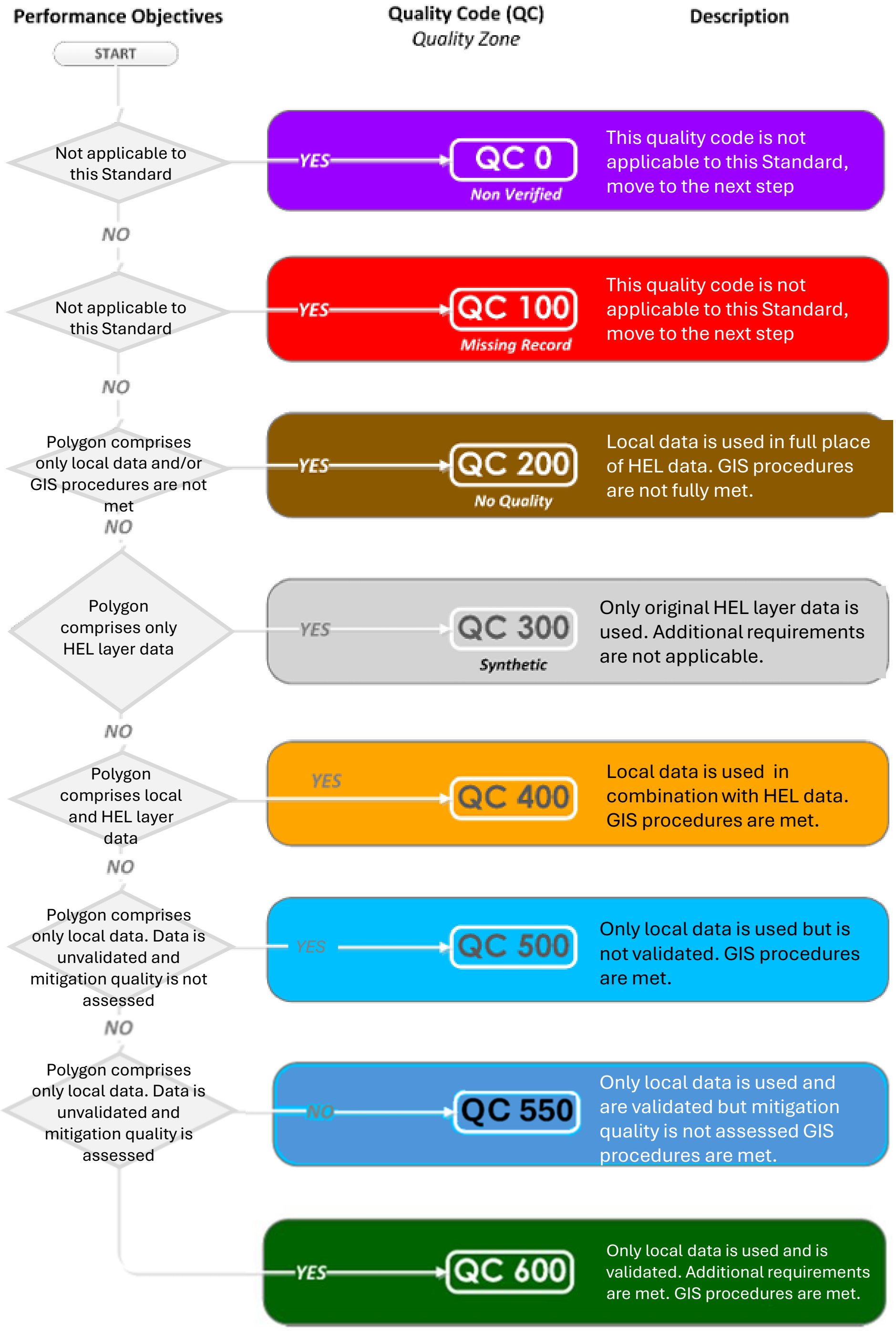

Figure 1 – Quality code flowchart

Quality coding matrix

	QC 200	QC 300	QC 400	QC 500	QC 550	QC 600
Erodible land data and validation (Sections 1, 2 and 4)	Local erodible land data are used. ☐	Only fundamental HEL layer erodible land data are used. Validation is not applicable. ☐	Local erodible land data are used in combination with LCDB or Woody layer land cover data, irrespective of validation and additional requirements. ☐	Local erodible land data are used in combination with local land cover or mitigation data. Local erodible land data are unvalidated. ☐	☐	Local erodible land data are used in combination with local land cover data. Additional requirements are met. ☐
Land cover or mitigation data and validation (Sections 1, 3 and 4)	Local land cover or mitigation data are used. ☐	Only LCDB or Woody layer land cover data are used. Validation is not applicable. ☐	Local land cover data are used in combination with fundamental HEL layer erodible land data, irrespective of Additional requirements. ☐	Local land cover data are used in combination with local erodible land data. Additional requirements are not met. ☐	Local land cover data are used in combination with local erodible land data. Data are validated. Mitigation quality not assessed. ☐	Local land cover data are used in combination with local erodible land data. Additional requirements are met. ☐
GIS procedures (Annex B)	Procedures are not met. ☐	Not applicable. ☐	Procedures are fully met. ☐	Procedures are fully met. ☐	Procedures are fully met. ☐	Procedures are fully met. ☐

Final quality code assigned from all matrices Select the lowest quality code ticked across all boxes.	QC =

Application

All data produced and archived under NEMS Standards shall be filed with all required metadata, including a quality code assigned in accordance with NEMS National Quality Code Schema. The schema permits valid comparisons within and across multiple data series. Quality coding also allows those interpreting analysis and reporting on erodible land and stabilisation mitigations to understand how confident they can be in the accuracy of the underlying data.

The quality coding flowchart as shown shall be used as the framework to assign quality codes to individual polygons within the modified (local) HEL layer.

Quality coding is assigned based on the source of the polygon's data, adherence to GIS procedures, and whether additional requirements relating to validation and mitigation quality assessment are met.

Where the national HEL layer only is used, an initial quality code of QC 300 is assigned to individual polygons. This initial quality code reflects the default confidence in the HEL model.

Polygons using a combination of national HEL layer data and local data are assigned a quality code of QC 400, provided GIS procedures are met; these data are considered compromised due to the mixture of sources but offer higher quality than QC 300 due to improved spatial resolution.

Polygons utilising unvalidated local data shall be assigned a quality code of QC 500, provided that all mandatory GIS procedures have been met. For local erodible land polygons, a quality code of QC 600 may be assigned where GIS procedures are met and the data have been validated using the methods detailed in this Standard. In the case of local land cover data, the highest quality code of QC 600 is only applicable if both data validation and a mitigation quality assessment have been successfully completed. If local land cover data have been validated but a mitigation quality assessment has not been carried out, a maximum quality code of QC 550 shall be assigned.

Quality codes are determined from the current version of the Standard at the time data are acquired, and there is no requirement to revise codes for archived data when the Standard is updated. The Standard and version applied must be tracked in the metadata via a Stationarity Comment. Practitioners should maintain in-house copies of the specific version of the Standard utilised to ensure future users have access to the applicable criteria for any given point in time.

1 About the Highly Erodible Land Model

In this section

The HEL model provides the baseline data used in this Standard. This section describes the HEL model components: the fundamental HEL layer, land cover information, and the final HEL layer.

1.1 Background

Highly Erodible Land (HEL) is a national indicator used in the environmental reporting series co-published by the Ministry for the Environment and StatsNZ.[7] The HEL model provides the data used for the HEL indicator reported by StatsNZ.

At the time of writing this Standard, the HEL layer – produced by the HEL model – is the best nationally available data for this purpose and has been adopted as the baseline data in this Standard.

The HEL model produces a 'fundamental HEL layer' that identifies land at high risk of soil erosion assuming no protective vegetation (Dymond et al., 2006; Dymond and Shepherd, 2023). The fundamental HEL layer is produced using a digital elevation model (DEM) by assigning a predetermined slope threshold to each erosion terrain. The slope thresholds and erosion terrains are listed in Dymond and Shepherd (2023).

The final HEL layer is derived by overlaying land cover information onto the fundamental HEL layer to identify land at high risk of soil erosion (erodible land without protective woody vegetation[8]). The land cover information for the HEL model is provided by the LCDB or the Woody layer.

The LCDB has six versions produced at the years 1996, 2001, 2008, 2012, 2018 and 2025.[9] At the time of writing this Standard (2025), the HEL model uses LCDB v5; updates to the HEL layer are limited by the frequency of LCDB updates. The minimum mapping unit of the LCDB is 1 ha.

The Woody layer is the other national layer of land cover information that can be used in the HEL model. The Woody layer is an automated update of basic land cover produced by applying spectral rules to satellite imagery (Dymond and Shepherd 2004). The Woody layer has seven versions (as used in the 2024 update of the HEL layer), produced from Sentinel-2 satellite imagery, at the years 2016, 2017, 2018, 2019, 2020, 2021 and 2022; it is updated more frequently than the LCDB and is at a higher resolution with a minimum mapping unit of 0.01 ha. Note that the Woody layer does not

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[7] https://www.stats.govt.nz/indicators/highly-erodible-land-data-to-2022/

[8] The HEL uses the terms 'protective vegetation cover' and 'protective woody vegetation'. More commonly, the term 'protective woody vegetation' is used because of the focus on stabilisation of mass movement erosion provided by the woody roots associated with woody vegetation. These terms are used in place of the term 'adequate vegetative protection', used for stabilisation of erosion by vegetation in general.

[9] https://lris.scinfo.org.nz/layer/123148-lcdb-v60-land-cover-database-version-60-mainland-new-zealand/

detect new plantings that have not yet formed a canopy. This means that, when refreshed, the Woody layer is likely to provide a more accurate representation of protective vegetation than regional planting datasets. Regional data may include recent plantings that have not yet developed protective function and may exclude plantings that are not recorded or known to the relevant regional authority.

The assumption of using the Woody layer in the HEL model is that vegetation - either planted or reverting - that has woody stems will also have woody roots, which are essential for stabilisation of highly erodible land.

For a regional-level baseline, the fundamental HEL layer, combined with the LCDB-based vegetation cover layer, the Woody layer, and/or regional layers of soil conservation mitigations can be used to establish the area of land without protective woody vegetation that is at high risk of mass movement erosion (Dymond and Shepherd, 2023).

1.2 Data sources

1.2.1 HEL data

Data for the HEL layer are freely available from MfE upon request (the data are too large to publish on their data service): [Highly erodible land, to 2022 | MfE Data Service](https://data.mfe.govt.nz/document/25197-highly-erodible-land-to-2022/).[10]

1.2.2 LCDB data

Current and past LCDB data for New Zealand can be sourced from the Manaaki Whenua Landcare Research[11] LRIS Portal. The link to the current version of the LCDB (LCDB v5.0 - Land Cover Database version 5.0, Mainland, New Zealand) is provided below.

https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

To allow for retrospective analysis of highly erodible land, the most current version of the LCDB can be used as it also contains vegetation cover for all timesteps.

1.2.3 Woody layer data

Current and past Woody layer data for the North Island and South Island can be sourced from the Manaaki Whenua Landcare Research LRIS Portal:

https://lris.scinfo.org.nz/layer/48183-ecosat-woody-north-island/

https://lris.scinfo.org.nz/layer/48184-ecosat-woody-south-island/

[10] https://data.mfe.govt.nz/document/25197-highly-erodible-land-to-2022/
[11] Now Bioeconomy Science Institute.

Metadata for these layers and a lookup table of the basic land cover classes are available via the above links.

1.3 Revision of HEL model data

In this Standard, the fundamental HEL layer, LCDB and Woody layer data used in the HEL model to identify highly erodible land can be replaced with finer-scale erodible land, land cover and stabilisation mitigation data to derive more accurate regional-level highly erodible land data. The term ‘local’ is used in this Standard to refer to data collected at a sub-regional scale, as described in section 2.

To ensure local data can be used for national-scale reporting, all polygons and attributes for erodible land, land cover and stabilisation mitigations derived using local data must also have the HEL model classes recorded (as listed in **Table 5**).

Further explanation of the fields and acceptable values for the fundamental HEL layer, LCDB and Woody layer are provided in Dymond et al. (2006), Dymond and Shepherd (2023) and in the sources of data described section 1.2 of this Standard.

Note: *Naturally bare or non-productive surfaces including permanent snow, ice, rock, and alpine herb fields are excluded from the national HEL model productive baseline. While LUC Class 8 is generally excluded under this definition, it shall be included in local data recording where it is identified as a significant sediment source. In such instances, the only technically valid mitigation record is Regenerating vegetation (retirement and reversion).*

Table 5 – Classes for land at risk of erosion, LCDB woody classes, and the Woody layer land cover classes used in the HEL model (adapted from Dymond and Shepherd, 2023).

ID	Description
Highly Erodible Land model classes of land at risk of erosion	
1	High landslide risk – delivery to stream
2	High landslide risk – non-delivery to steam
3	Moderate earthflow risk
4	Severe earthflow risk
5	Gully risk
LCDB woody classes	
2	Urban park
33	Orchard and Vineyard
47	Flaxland
51	Gorse/Broom
52	Manuka/Kanuka
54	Broadleaved Indigenous Hardwoods
55	Subalpine Shrubland
56	Mixed exotic shrubland
58	Grey Scrub
68	Deciduous Hardwood
69	Indigenous Forest
70	Mangrove
71	Exotic Forest
Basic land cover classes in the Woody layer	
1	Water
2	Bare Ground
3	Woody Vegetation
4	Herbaceous Vegetation
6	Primarily Bare
7	Snow

2 Local Erodible Land Data

In this section

Local erodible land data can be used under this Standard to replace data in polygons of local copies of the national-level fundamental HEL layer. This section provides the requirements for recording erosion type and severity used for standardising local erodible land data, describes the sources of local erodible land data that are acceptable in this Standard, and describes the relationship between local erodible land data and fundamental HEL layer erodible land data.

2.1 Background

Decisions about land use and management are often influenced by the type and severity of erosion; therefore, it is important that the classes used and the methods of assessment are consistent and objective. Classification of erodible land in this Standard is based on erosion type and severity. The *Land Use Capability Survey Handbook* (Lynn et al., 2009) (henceforth 'LUC Handbook') provides the basis for classification. LUC erosion types are defined in Appendix 2 of the LUC Handbook. Examples and guidelines for assessing erosion severity are provided as bullet point lists on pages 28 to 43 of the LUC Handbook.

To allow for consistent national data aggregation and reporting, erosion types and severity specific to this Standard must also be classified as one of the HEL model erosion types.

Assessment of erosion severity is an area where better definitions and standards are required. This is because defining erosion severity depends on the soil, climate and rock features at the specific location. Until thorough standards for erosion assessment are provided, guidance should be sought from regional LUC classification reports and extended legends[12] or an SCP. This is important to maintain objectivity and consistency with existing mapping so that the data remains nationally and regionally meaningful.

2.2 Erosion type classification

The acceptable assessments for determining erosion type are:

- modelled erosion susceptibility or risk, and
- assessment by an SCP. This can be by desktop assessment, field (on-ground) assessment, or a combination of both.

The erosion types provided by the LUC Handbook (3rd edition) are required for the classification by this Standard. Additional erosion risk classes for farm-scale

[12] Regional LUC classification reports and extended legends are available in Bioeconomy Science Institute's Land Use Capability (LUC) Archive - https://cdm20022.contentdm.oclc.org/digital/collection/p20022coll27

assessment can be used but must be correlated to both LUC Handbook erosion types and HEL layer erodible land classes.

To ensure national consistency when refining or validating erodible land data, geomorphic Slope Thresholds specific to the underlying terrain shall be applied. These thresholds define the angle at which land is classified as HEL in the absence of protective woody vegetation. Likely Slope Thresholds for regional authorities (e.g. 24° for Tertiary Soft rock, 26° for Loess or Tephra, and 28° for Hard rock Hill Country) are provided as a guide in the comprehensive list in Annex A: Geomorphic Slope Thresholds.

Table 6 provides the approximate correlation between the raster-based HEL layer and the vector-based LUC Handbook erosion type classes. The HEL model utilises pixel-based logic to identify erodible land, whereas LUC classifications are applied to LUC units (vector polygons). Consequently, the correlations in Table 6 represent the dominant erosion process expected within a terrain rather than a 1:1 spatial overlap of boundaries.

Table 6 – Correlation between the HEL layer and LUC Handbook erosion type classes.

HEL layer classification (Dymond and Shepherd, 2023)	LUC Handbook classification (Lynn et al., 2009)	LUC Handbook erosion severity (Lynn et al., 2009)
High landslide risk – delivery to stream	Soil slip on terrain typically classified as LUC Class 6e or 7e	Moderate to severe
High landslide risk – non-delivery to steam	Soil slip on terrain typically classified as LUC Class 6e or 7e	Moderate to severe
Moderate earthflow risk	Earthflow or Slump on deep-seated terrain	Moderate to severe
Severe earthflow risk	Earthflow or Slump on deep-seated terrain	Severe to very severe, extreme
Gully risk	Gully or Tunnel gully on any LUC Class	Severe to extreme

Note: For the purposes of standardisation, the classification of erosion types shall adhere to specific technical requirements. The soil slip category includes shallow failures occurring on colluvial foot slopes that are commonly referred to as earth slips. Earthflow identification is based on geomorphic diagnostics, specifically a characteristic hummocky or uneven ground surface and the presence of a bulging toe at the downslope limit. Gully features shall be recorded across all LUC classes, where they represent an active or significant sediment source. Gullies are classified based on geomorphic form and active incision; they are included as erodible land notwithstanding the slope thresholds defined in Annex A.

2.3 Erosion severity

Classification of erosion severity is defined by the LUC Handbook, regional LUC classification documents or an SCP. The acceptable assessment methods for determining erosion severity are:

- modelled erosion severity, and
- assessment by an SCP. This can be by desktop assessment, field (on-ground) assessment, or a combination of both.

Table 7 provides guidelines for relating the area or size of bare ground to erosion severity for specific erosion types. These guidelines are based on Table 8 (pages 24 and 25) of the LUC Handbook. For a robust and objective assessment, these benchmarks should be used in conjunction with regional LUC classification reports, extended legends, and technical descriptions found in supporting publications.

Table 7 – General erosion severity classes, and corresponding area (as a percentage of total area) or size (hectares) of bare ground, for erosion types at a regional scale. Reproduced from Table 8 of the LUC Handbook (pp24-25).

		Soil slip	Earthflow	Gully	Tunnel
Symbol	Severity	Area (%)	Size (ha)	Size (ha)	Area (%)
0	negligible	<0.5	0	0	<0.5
1	slight	0.5–2	<0.5	<0.05	0.5–2
2	moderate	2–5	0.5–1	0.05–0.5	2–5
3	severe	5–10	1–5	0.5–1	5–10
4	very severe	10–20	5–10	1–5	10–20
5	extreme	>20	>10	>5	>20

Field assessments of severity may differ from these regional guidelines because they incorporate site-specific factors such as the difficulty of repair or current erosion activity. Activity is assessed by the degree of surface disruption and active bare ground, which is particularly relevant for complex features like earthflows and gullies.

Furthermore, bare ground percentages for a given severity ranking typically increase as the mapping scale becomes finer (moving from regional to farm scale). At a regional scale (e.g. in the NZLRI), polygons have an average size of 100 ha and necessarily include 'diluting' areas of less erodible land within the boundary. Conversely, farm-scale units (averaging 10 ha) allow polygons to be drawn more precisely around erodible features, thereby excluding non-erodible land and resulting in a higher proportion of bare ground within the identified area

2.4 Delivery to stream

In the HEL model, *delivery to stream* is a critical classification used to distinguish between areas of *high landslide risk* that are likely to send sediment directly into the stream network and those that are not. This distinction is important because it highlights areas where soil conservation efforts will be most effective at reducing sediment yield into rivers, which is a major environmental concern.

In the HEL model, *delivery to stream* is determined through a spatial analysis process applied to all pixels identified as having high landslide risk (steep land without protective woody vegetation). A DEM is used to calculate the flow path, or streamline, from the susceptible pixel down to the nearest watercourse. The land is classified as *high landslide risk – delivery to stream* if this flow path does not encounter a significant area of flat land. Specifically, significant flat land is defined as three consecutive pixels with a slope of less than five degrees. If such a feature is encountered, the pixel is labelled as *high landslide risk – non-delivery to stream*, as the sediment is presumed to deposit on the flat land before it can reach the watercourse.

Other erosion models may also estimate sediment delivery to streams from landslides. For example, the morphometric connectivity model developed by Spiekermann et al. (2022a; 2022b) uses statistical methods to calculate the probability that sediment from a shallow landslide will reach the stream network, and then classifies landslides as *connected* or *unconnected* based on that probability.

Sediment delivery to streams can also be determined manually through field surveys and the desktop interpretation of high-resolution aerial imagery. The manual assessment method involves utilising current and historical high-resolution aerial imagery as the primary data source. The process involves manually interpreting aerial imagery to delineate the precise location and boundaries of landslide scars, as well as their corresponding debris runout paths. The degree of sediment connectivity is then visually inferred by observing the debris trail. Based on this observation, the feature is classified: if the debris tail extends to and merges with a stream channel, it is classified as *delivered*; conversely, if the debris is deposited on the slope away from the channel, it is classified as *non-delivered*.

This Standard accepts either modelled or manual assessment methods, provided they are capable of providing the data required to inform the *delivery to stream* for *high landslide risk*.

The acceptable methods for determining *delivery to stream* for *high landslide risk* are:

- modelled erosion connectivity using a published model, and
- manual assessment by an SCP. This can be by desktop assessment, field (on-ground) assessment, or a combination of both.

2.5 Sources of local erodible land data

The two sources of local erodible land data are:

- local modelled data, and
- local mapped data (including mapped LUC data).

All erodible land data must have an erosion type and severity classification.

2.6 Modelled erodible land data

Regionally developed models that predict erosion types can be used to provide more detailed erodible land data than the fundamental HEL layer's data. It is common for regionally developed models to be erosion-type specific and coverage can be sub-regional in extent.

Airborne LiDAR information provides an opportunity to improve spatial resolution and distinguish between digital elevation (bare earth) and digital surface models (elevation augmented with natural and human features) (North et al., 2002).

LiDAR coverage is currently about 80% of New Zealand.[13] The improvement in spatial resolution from LiDAR could be used to gain spatial resolution for slope information and to create canopy height models. There is increasing potential for regional authorities to utilise LiDAR within regional erosion models to improve erosion characterisation and spatial extent.

2.6.1 Recent erosion model developments

Smith et al. (2024) developed object-based methods for mapping landsides from orthophotography (c. 50 cm) for application over large study areas. The model used machine learning techniques to predict the spatial probability (range 0-1) of landslide occurrence based on geo-environmental data and was applied in the Hawke's Bay and Gisborne regions. The increased spatial detail of the model enables improved targeting of soil conservation to erodible land at farm scale. There is potential for the model to be expanded to other regions with LiDAR coverage to increase spatial resolution of the slope factor influencing land susceptibility to erosion but would require cross-validation using landslide inventories from previous events. It is worth noting that the model still relies on NZLRI data with mapping scales of 1:50,000 for land cover and rock type data. Additionally, modelling of earthflow erosion is not yet possible.[14]

More recently, methodologies have been developed to model landslide risk using satellite imagery and machine learning. For example, a rapid assessment following Cyclone Gabrielle used change detection algorithms on Sentinel 2 satellite imagery to identify over 300,000 landslides across the North Island (McMillan et al., 2023). Their model focused on Land Use Capability (LUC) Classes 6 and 7, where most landslides occur, to minimise false positives from agricultural practices. The analysis disaggregated landslide damage by land cover class, territorial authority, and slope, providing empirical evidence of the relationship between these factors. This kind of granular data is vital for assessing land vulnerability. For example, the Cyclone Gabrielle

[13] Provincial Growth Fund - LiDAR Elevation Data Capture Project | Toitū Te Whenua - Land Information New Zealand.
[14] Malcolm Todd. 2025. Pers. Comm. September 2025.

assessment found that while woody vegetation generally reduces landslide probability by 90% in some regions, its effectiveness dropped significantly in others due to underlying geology, such as the prevalence of sandstone in the Gisborne coastal hill country.

2.6.2 Sources of data

The source of the data will vary depending on the erosion model used. The use of models varies from region to region. For the model to be an acceptable source of local erodible land data it must be supported by a published method.

2.7 Mapped erodible land data

Some regional authorities may maintain their own mapped erosion type or erodible land data separate to HEL layer data. These data may cover all or part of the region. Methods for mapping regional erosion and erodible land data are variable but generally involve a mix of visual interpretation of aerial photography and on-ground mapping.

A further source of erodible land data is LUC mapping undertaken as part of farm plans, such as the Whole Farm Plans developed as part of the Sustainable Land Use Initiative (SLUI) by Horizons Regional Council and the Hill Country Farm Plans developed by Taranaki Regional Council.[15] Erosion type and severity are recorded in the detailed physical inventory for LUC units, following the LUC Handbook LUC classification criteria. A detailed description of erosion type and guidelines for severity classification is provided in the LUC Handbook.

Aerial photograph interpretation methods have also been used to assess soil stability (Burton et al., 2009). The assessment includes identifying and recording erosion types. However, the method generally uses a grid-based sampling approach that does not allow for mapping of areas and the creation of polygons. This assessment approach is best used for independent validation of polygons (see section 4.2 – Data validation).

The assumption in this Standard is that, in general, the scale of local data capture is finer than that of the fundamental HEL layer erodible land data, therefore, the data can provide improved resolution for determining erodible land and highly erodible land. This Standard allows the use of local erodible land data to replace the fundamental HEL layer erodible land data used in the HEL model.

2.7.1 Sources of data

Acceptable sources of mapped local erodible land data are:

- locally mapped erosion data following LUC Handbook criteria, and
- locally mapped erosion types and severity associated with LUC mapping and following LUC Handbook criteria.

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[15] https://www.horizons.govt.nz/managing-natural-resources/land; https://www.trc.govt.nz/environment/farmhub/farm-plans/hillcountry-farm-plans.

The Standard acknowledges that methods used and completeness vary from region to region.

3 Local Land Cover and Mitigation Data

In this section

This section describes the sources of land cover and stabilisation mitigation data, including acceptable sources of data, methods for collection and data attributes for use in this Standard.

3.1.1 Background

The HEL model uses the LCDB or the Woody layer to identify where erodible land has protection and is therefore not classed as highly erodible land. More detailed land cover and mitigation data can be used in place of the LCDB or Woody layer land cover data. This data can be sourced from regional assessment, either by desktop or on-ground methods.

3.1.2 Data sources

Acceptable sources of local land cover data are:

- locally mapped land cover data, and
- locally mapped soil conservation (stabilisation) mitigation data.

3.2 Local land cover data

Some regional authorities have indicated that they maintain their own land use/cover layers separate to LCDB data. These data may cover all or part of the region. Methods for compiling local land use/cover data are variable but generally involve a mix of visual interpretation of aerial imagery and on-ground mapping. The assumption is that, in general, the scale of local data capture is finer than that of the LCDB; therefore, the data can provide improved land cover resolution for determining whether erodible land is protected. This Standard allows local land cover data to be used to replace existing lower-detail land cover data (such as LCDB and Woody layer data) used in the HEL model.

Aerial imagery interpretation methods have also been used to assess soil stability (Burton et al., 2009). The assessment includes identifying and recording land use/cover. However, the method generally uses a grid-based sampling approach that does not allow for mapping of areas and the creation of polygons. This assessment approach is best used for independent validation of polygons (see section 4.2 – Data validation).

3.2.1 Sources of data

Data acquisition method specifications for local land cover data need to be recorded. For example, whether the data were collected using aerial photograph interpretation, on-ground mapping or a combination of both should be recorded.

Acceptable sources of local land cover information are:

- aerial imagery and LiDAR-based interpretation, and
- farm plans.

Regional land cover classes need to be correlated with LCDB classes and Woody layer vegetation classes used in the HEL model.

3.3 Local mitigation data

The LCDB does not map individual trees, such as the space-planted poplars commonly used in soil conservation, and so the impact of some soil conservation actions is not included. Information on specific soil conservation mitigations from sources such as farm plans is recommended to be included in the HEL model in the future to improve its accuracy.

Methods have been developed to map individual trees associated with soil conservation / stabilisation mitigations by combining regional LiDAR data (1 m resolution) with orthophotography (30 cm resolution). These high-resolution data are used to create models that quantify the effectiveness of individual trees in controlling landslide erosion (Spiekermann et al., 2022a, 2023).

Extending these high-resolution methods to a regional and national scale remains a challenge, which currently limits their application in national mitigation effectiveness indicators. This is partly due to the lack of complete national LiDAR coverage, even though it is increasing, and the cost of the analysis required.

The method of Burton et al. (2009) to assess soil stability includes identifying and recording the presence of soil conservation treatments (types of mitigation). However, as mentioned in section 2.7, the method does not allow for mapping of areas and the creation of polygons. This assessment approach is best used for independent validation of polygons (see section 4.2 – Data validation).

3.3.1 Sources of data

Data acquisition method specifications for local mitigation data need to be recorded. For example, whether the data were collected using aerial photograph interpretation, on-ground mapping or a combination of both should be recorded.

Acceptable sources of local mitigation information are:

- aerial photographic-based interpretation, and
- farm plans.

Local classes need to be correlated with LCDB classes and Woody layer vegetation classes used in the HEL model.

3.3.2 Mitigation classes

Mitigation classes used in this Standard are provided in **Table 8**.

Table 8 – Mitigation classes used in this Standard.

Mitigation class	Description
Spaced trees (standard spaced)	Trees (usually poplars) planted at regular intervals (approximately 20 m apart) to increase the strength of soil.
Spaced trees (closer spaced)	Trees (usually poplars) planted at close intervals (approximately 8-10 m apart) to increase the strength of soil.
Indigenous planted forest	Planted indigenous forest.
Exotic plantation forest	Planted exotic forest with rotational harvesting. Regions with large areas of land in forestry may need to consider forestry rotation cycles to account for large variations in HEL where these are due to areas being felled or maturing in specific years (Dymond and Shepherd, 2023).
Exotic continuous-cover forest	Planted exotic forest with no rotational harvesting (e.g. pine plantations for carbon sequestration).
Regenerating vegetation (retirement and reversion)	Retirement of land – pastoral land may be retired from production by fencing to exclude stock and animal pests. Retired land will progress through weeds to shrubs/scrub and eventually to indigenous forest. Reversion – reversion of pasture back to scrub by excluding stock and animal pests and allowing vegetation to grow.

4 Additional Requirements

In this section

Additional requirements are necessary to meet QC 600. This section describes these requirements including validation of erodible land, land cover and mitigation data, and mitigation quality (mitigation appropriateness and effectiveness).

4.1 Pre-amble: data validation vs. mitigation quality assessment

It is important to distinguish between data validation and mitigation quality assessment, though both are integral to achieving the highest quality code (QC 600).

Data validation is the process of confirming that a polygon's classification—whether it represents erodible land, land cover, or a mitigation—accurately matches the on-the-ground reality (Dymond and Shepherd, 2023; Todd and Kosik, 2022). This process verifies the existence and location of a mitigation polygon, correcting for any spatial inaccuracies, which are common in manually digitised data (Todd and Kosik, 2022; Rees and Todd, 2021).

In contrast, mitigation quality assessment is the evaluation of the mitigation's performance and suitability after its existence has been validated. The mitigation quality assessment measures effectiveness and appropriateness, using quantitative thresholds for bare ground and canopy cover metrics. Existing methods, such as the point sample analysis developed by Hicks (2005a, 2005b) and Burton et al. (2009), are highly suitable for this purpose as they can be adapted to collect the required data to inform these effectiveness thresholds. On-ground audits like those conducted by Horizons (Rees and Todd, 2021; Todd and Kosik 2022), Northland (Ballinger, 2024) and Greater Wellington (n.d.) regional councils are also acceptable methods provided they gather (or can be modified to gather) the detailed, granular data necessary to complete a quality assessment.

4.2 Data validation

4.2.1 Background

Validation is the process of confirming that the on-the-ground reality matches the classifications in a GIS layer. The Standard assumes that data quality is improved if independent validation has been performed. Validation is applied at the level of individual polygons and must be undertaken by, or under the supervision of, an SCP. Validation allows an SCP to verify that a polygon's assigned classification—be it erodible land type, land cover, or a specific mitigation—is accurate. This increases the data's level of certainty and is a crucial step for distinguishing between real-world changes and those that are simply due to data quality issues.

Validation can be undertaken at any time, either as data become available or after mitigations are established. It can be applied independently to erodible land, land cover, and mitigation layers, or to a combination of these layers. The Standard acknowledges that a mix of validation methods can achieve robust results, allowing for regional methods to be used in conjunction with this Standard.

4.2.2 Validation methods

The Standard accepts two primary validation methods—desktop and on-ground validation—which can be used individually or in combination. There is no quality differentiation between these methods, as they are often used to complement each other. Validation must be independent, meaning that the SCP undertaking the validation must not have been the original creator or provider of the data.

Validation must be recorded for each polygon and include all required attributes. The SCP is responsible for ensuring the data captured are accurate and consistent. Model validation, which is undertaken to develop regional models, is not considered validation for the purpose of assigning a level of certainty in this Standard.

4.2.2.1 Desktop validation

Desktop validation involves a visual assessment using aerial imagery by an SCP using up-to-date, high-resolution imagery such as aerial imagery and LiDAR data (Burton et al., 2009). The SCP will review a polygon to confirm its erosion type and severity, land cover, or mitigation classification. This method is also an efficient way to check for major discrepancies before a field visit.

An example of an acceptable desktop validation method is provided by Burton et al. (2009), as 'Chapter 4: Assessing soil stability' in *Land and Soil Monitoring: A guide for SoE and regional council reporting*. The chapter includes methods for assessing land cover and land use as well as bare ground and soil stability. If undertaken independently, the assessment could be used to objectively validate both erodible land and land cover and mitigation polygons.

4.2.2.2 On-ground validation

On-ground validation is a more robust approach that requires a physical site visit to collect data. The SCP uses standardised and repeatable methods, such as in-field plot assessments, to verify a polygon's classification. On-ground validation is particularly useful for independently verifying desktop assessments and confirming if erodible land and mitigation classifications are as they are represented in the data. All validation of erosion type and severity must be in accordance with the LUC Handbook criteria to ensure consistency and objectivity.

Validation of land cover and mitigations is undertaken against the LCDB vegetation classes, Woody layer classes, and, for mitigations only, the Standard's mitigation classes.

4.3 Mitigation quality assessment

4.3.1 Background

Mitigation quality involves an assessment of the appropriateness of the vegetation-based mitigation for a specific erosion type and severity, as well as the effectiveness of the mitigation after it has been established. It is the *assessment* of this quality that contributes to the overall quality coding of a polygon, not the quality of the mitigation itself.

The development of a standardised method for assessing the effectiveness of soil conservation has been an ongoing effort in New Zealand (Burton et al., 2009). This Standard draws on methodologies like the point sample analysis technique developed by Waikato Regional Council (Hicks, 2005a; Hicks 2005b) and the Land Monitoring Forum (Burton et al., 2009). The point sample analysis approach provides a repeatable way to monitor soil stability using a GIS framework and high-resolution aerial imagery to assess land attributes within a defined one-hectare area (Hicks, 2005b; Burton et al., 2009). The method directly assesses four critical elements of soil conservation effectiveness: whether land needs treatment, what type of treatment is necessary, what treatment is currently present, and if its extent is sufficient to control erosion (Hicks, 2005a; Hicks 2005b).

Research has shown that the effectiveness of a vegetation-based mitigation is assessed using quantitative measures directly tied to the type of erosion feature being addressed. For instance, a mitigation vegetation cover of 10% to 20% may be sufficient for gully erosion, while a higher cover of over 90% is generally needed for landslides (Hicks, 2005b). This demonstrates that a universal threshold is not supported by evidence. To address this, the Standard employs a more sophisticated, two-part assessment based on quantitative measures of bare ground and canopy cover. These measures provide a direct, verifiable link to soil stability and protective vegetation, and their thresholds are tailored to the specific erosion type of the polygon.

4.3.2 Acceptable assessment methods

This Standard accepts a range of assessment methods, provided they can collect the data required to inform the appropriateness and effectiveness assessments and their thresholds.

Assessment must be independent, meaning that the SCP undertaking or supervising the assessment must not have been the original creator of the data.

Both desktop and on-ground methods are acceptable as they each offer unique strengths in the assessment process. Desktop methods are efficient for broad-scale, statistically robust surveys, while on-ground methods provide the granular, high-confidence data needed for a comprehensive quality assessment. Known acceptable methods for mitigation assessment are provided in **Table 9**. It should be noted that other regional authorities (not listed in Table 9) may have similar acceptable methods for mitigation quality assessment. Provided they collect the data required to inform the appropriateness and effectiveness assessments, other methods can be used.

Table 9 – Known acceptable methods for mitigation quality assessment.

Method	Regional authority	Method (desktop, on-ground or a combination)	Description of method	Applicable mitigation(s)
Point Sample Analysis	Environment Waikato/Land Monitoring Forum	Desktop	Uses a grid of points on high-resolution aerial imagery to assess land attributes. Measures bare ground and vegetation cover for regional/catchment-scale surveys (Hicks, 2005a; Hicks, 2005b; Burton et al., 2009).	All mitigation types, especially large-scale ones like afforestation and reversion.
SLUI On-Ground Audit	Horizons Regional Council	On-ground	Involves a field visit to a sample of farms to document survival, effectiveness score, fence integrity, and threats like pests and drought (Todd & Kosik, 2022; Rees &Todd, 2021).	All vegetative mitigations (spaced planting, afforestation, retirement).
Survey123 Pole Auditing	Greater Wellington Regional Council (GWRC)	On-ground	Uses a mobile app to collect granular data on a per-polygon basis. Focuses on counts of live/dead/marginal poles, reasons for death, and presence of pests (GWRC, n.d.).	Spaced planting.
Poplar and Willow Survival Audits	Northland Regional Council	On-ground	Audits of pole plantings to evaluate clonal performance and survival rates. Assesses survival based on planting material and identifies causes of failure such as pests and drought (Ballinger, 2024).	Spaced planting.

Using the Point Sample Analysis in Table 9 as an example, the original mitigations are implemented and recorded by Waikato Regional Council land management staff in collaboration with individual landowners. The Point Sample Analysis assessment is subsequently undertaken by an independent (contracted) SCP using aerial imagery. Data from the Point Sample Analysis can then be used to provide the mitigation quality assessment where the assessment spatially overlaps with the original soil conservation works (mitigation) as recorded in Waikato Regional Council data.

For the on-ground verification methods, the SCP assesses the mitigation establishment typically 5–10 years after planting (see subsection 4.3.3). To ensure true independence, the assessment shall not be undertaken by anyone involved in implementing or recording the mitigation.

4.3.3 Timing and frequency of assessment

The frequency and timing of assessments are critical for accurately measuring mitigation effectiveness. An assessment programme must be practical and sustainable over time and is usually constrained by staff capacity (Todd and Rees, 2021). It is important to consider the age and maturity of the mitigation when conducting assessments, as land is recorded as mitigated only when protective woody vegetation provides structural reinforcement at the soil and regolith interface.

On-ground assessments are most effective for capturing true initial establishment (survival rates) when trees are just over a year old, having gone through a full summer and autumn (GWRC, n.d.). At the stage of implementation, assessments are used to verify that the mitigation is appropriate for the landform. For desktop assessments, aerial imagery is less reliable for assessing spaced plantings when the trees are too young to be visible, often requiring them to be at least five years old before they can be confidently identified or corrected from imagery (Todd and Kosik, 2022).

Soil conservation mitigations such as afforestation with exotic plantation forest or exotic continuous-cover forest are generally considered to reach full establishment for erosion control after approximately 10 years. Spaced trees are generally considered to reach full establishment after approximately 15 years, provided they meet specific density and spacing requirements (Ministry for the Environment, 2001). Standard spaced trees must reach a minimum density of 25 stems per hectare at their final intended spacing (equating to an average 20-metre grid), while closer spaced trees are those planted at higher densities to address specific high-risk features.

Indigenous planted forest and regenerating vegetation (retirement and reversion) typically require longer periods to reach full establishment. For retired land (including LUC Class 8 land identified as a significant sediment source), effectiveness requires physical evidence of the natural reversion to woody cover (Ministry for the Environment, 2001). The distinction between developing and mature mitigations is critical for understanding the limitations of each assessment. In general, mitigation appropriateness is assessed following implementation, while initial establishment is confirmed after one year. Mitigation effectiveness is only recorded once the measure reaches full establishment, typically 5 to 15 years post-implementation depending on the species and site conditions.

4.3.4 Mitigation appropriateness

Mitigation appropriateness is determined by assessing whether the mitigation type is a suitable strategy for the specific erosion type and severity of the land it is applied to.

There are no published references that clearly define appropriate mitigations for all soil conservation requirements across New Zealand. For this Standard, appropriate mitigations for erosion type and severity have been determined based on the expert knowledge of the members of the NEMS Working Group. The Group's primary focus in developing this matrix was to identify and exclude mitigations that are not appropriate, as technically mismatched measures which do not address the cause of the erosion are not used to claim that the risk has been managed.

In alignment with established soil conservation survey methods (Hicks, 2005a), appropriateness is also used as a contributing measure of mitigation quality (see section 4.3.7 Mitigation quality classification). Under this Standard, a mitigation is considered appropriate only if the mitigation type is technically suited to the geomorphic process and has not been specifically excluded for that erosion type and severity. These requirements for mitigation appropriateness are set out in **Table 10**.

Table 10 – Appropriateness of mitigations for erosion type and severity.

HEL erosion category	Erosion type(s)	Mitigation(s)	Slight to moderate erosion severity	Severe, very severe, extreme erosion severity
Landslide (delivery to stream)	Soil slip	Spaced trees (closer spaced)	Appropriate	Appropriate
		Spaced trees (standard spaced)	Appropriate	Not appropriate
		Indigenous planted forest	Appropriate	Appropriate
		Exotic continuous-cover forest	Appropriate	Appropriate
		Exotic plantation forest	Appropriate	Appropriate
		Regenerating vegetation (retirement)	Appropriate	Appropriate
Landslide (non-delivery to stream)		Spaced trees (closer spaced)	Appropriate	Appropriate
		Spaced trees (standard spaced)	Appropriate	Not appropriate
		Indigenous planted forest	Appropriate	Appropriate

		Exotic continuous-cover forest	Appropriate	Appropriate
		Exotic plantation forest	Appropriate	Appropriate
		Regenerating vegetation (retirement)	Appropriate	Appropriate
Moderate earthflow risk	Earthflow Slump	Spaced trees (closer spaced)	Appropriate	Not applicable
		Spaced trees (standard spaced)	Appropriate	Not applicable
		Indigenous planted forest	Appropriate	Not applicable
		Exotic continuous-cover forest	Appropriate	Not applicable
		Exotic plantation forest	Appropriate	Not applicable
		Regenerating vegetation	Appropriate	Not applicable
Severe earthflow risk		Spaced trees (closer spaced)	Not applicable	Not appropriate
		Spaced trees (standard spaced)	Not applicable	Not appropriate
		Indigenous planted forest	Not applicable	Appropriate
		Exotic continuous-cover forest	Not applicable	Appropriate
		Exotic plantation forest	Not applicable	Not appropriate
		Regenerating vegetation (retirement)	Not applicable	Appropriate
Gully	Gully Tunnel	Spaced trees (closer spaced)	Appropriate	Not appropriate
		Spaced trees (standard spaced)	Appropriate	Not appropriate
		Indigenous planted forest	Appropriate	Appropriate

		Exotic continuous-cover forest	Appropriate	Appropriate
		Exotic plantation forest	Not appropriate	Not appropriate
		Regenerating vegetation (retirement)	Appropriate	Appropriate

Note: While Table 10 identifies appropriate vegetation-based mitigation, it is recognised that for specific erosion processes such as earthflows or gully migration, complementary measures such as sub-surface drainage or runoff control engineering may be required to achieve the necessary reduction in sediment yield. Where these measures are used, they must be integrated with the appropriate vegetation types identified in the table to ensure a holistic approach to stability.

4.3.5 Mitigation effectiveness

There are no definitive methods for determining mitigation effectiveness. Effectiveness assessments are generally undertaken by regional authorities, which has historically resulted in a variety of approaches. Most commonly, regional authorities use simple measures of percentage plant survival, canopy cover, and bare ground to determine effectiveness. Given this current variability, the NEMS Working Group determined that the assessment should be based on an assessment by an SCP, with the specific method of assessment decided by the SCP.

In addition to assessment by an SCP, this Standard includes interim quantitative measures for mitigation effectiveness. A mitigation is considered fully effective when it reaches a state of maturity where it provides maximum protection against soil failure. For vegetation-based mitigations, this is defined by the point at which root reinforcement and canopy cover (where applicable) reach specific technical thresholds.

These quantitative measures are a first attempt at standardisation, acknowledging that substantiating data are currently limited. The purpose of recording these measures is to assist the future development of more robust quantitative thresholds. This Standard defines thresholds for mitigation effectiveness using two quantitative measures: bare ground (%) and canopy cover (%).

For all mitigation types, bare ground of ≤2% is taken to be fully effective. This threshold is directly informed by the erosion severity guidelines in the LUC Handbook (Table 8, p. 24), where ≤2% represents the upper limit of the 'slight' severity category for soil slip, tunnel gully, and rill erosion. By setting the effectiveness threshold at this level, the Standard ensures that land is classified as 'fully effective' only when active erosion is maintained at negligible or slight levels. In the LUC system, 'moderate' severity begins at >2%, marking the point where erosion processes begin to have a more significant impact on land stability and management. While identifying very small patches of bare ground can be technically challenging, a 2% threshold provides a verifiable standard for manual interpretation using high-resolution aerial imagery.

For planted forest or regenerating vegetation mitigations, fully effective canopy cover is taken to be ≥90% cover. This threshold represents the stage where the canopy provides maximum interception and root reinforcement, although the precision of this measurement is highly dependent on the scale of digitisation. Where high-precision, tight digitisation is used around the vegetation, a 90% threshold serves as a reliable indicator of functional effectiveness. Conversely, given the inherent variability in spaced trees regarding planting density and varieties used, a specific canopy cover threshold for those mitigations is not provided in this Standard. For a mitigation to be classified as 'fully effective', it must meet the specified bare ground threshold and, where applicable, the canopy cover threshold as detailed in **Table 11**.

Table 11 – Thresholds for mitigation effectiveness.

Mitigation effectiveness measure	Mitigation type(s)	Fully effective	Not fully effective
Bare ground (%)	All mitigation types	≤2% bare ground	>2% bare ground
Canopy cover (%)	Spaced trees (standard or closer spaced)	Not applicable	Not applicable*
Canopy cover (%)	Planted forest / Regenerating vegetation	≥90% cover	<90% cover

* Note: Refer to Section 4.3.3 for stem density and root development proxies used to determine effectiveness for spaced trees

Note: Bare ground for a given mitigation can vary depending on the occurrence of rainfall-induced erosion events and the precision of the assessment method (McMillan et al., 2023; Hicks, 2005b).

Note: The quantification of mitigation effectiveness is highly sensitive to the scale of spatial assessment and digitisation. Broad-scale landscape assessments typically report lower average effectiveness because they aggregate treated and untreated areas within a single land unit. Conversely, high-precision digitisation—focused specifically on the footprint of established vegetation—demonstrates that functional effectiveness (soil stability) reaches ≥90% as canopy closure and root-soil overlap are achieved. For the purposes of this Standard, the ≥90% threshold assumes a high-resolution assessment of the specific mitigated area.

4.3.5.1 On-ground assessment considerations

To achieve QC 600, mitigation quality must be assessed following vegetation establishment using a standardised approach to data collection. These assessments require specific field tools and methodologies to ensure that results are technically verifiable and repeatable.

In general, the assessment will require:

- a standardised checklist or data recording application (e.g. Survey123),

- methods or tools for accurate location identification and georeferencing (e.g. a GPS-enabled device or GNSS receiver),
- a tool to measure canopy cover (e.g. a spherical densitometer or canopy cover photo application),
- a method/tool to measure bare ground (e.g. visual estimation of bare ground for a representative standardised plot area),
- a standardised method to measure bare ground (e.g. visual estimation within a representative plot area),
- a method to assess survival (e.g. a 50-step transect count or a representative plot count),
- a method to assess fencing integrity and external threats (e.g. visual assessment of animal pest browsing or fence-line condition), and
- a camera or mobile device capable of capturing geo-referenced photographs.

4.3.6 Mitigation quality classification

The appropriateness and effectiveness assessment outcomes are combined into a mitigation quality assessment (**Table 12**), which in turn informs the polygon's overall mitigation quality status and any required remedial actions. This provides a clear, actionable result for land managers and funders.

Table 12 – Mitigation quality classification.

Classification	Description
High	The mitigation is appropriate and meets or exceeds effectiveness thresholds, indicating successful implementation and performance (fully effective).
Moderate	The mitigation is appropriate and meets one of the effectiveness thresholds but requires remedial actions to improve effectiveness.
Low	The mitigation is not appropriate, or appropriateness has not been assessed or does not meet the effectiveness thresholds. This indicates a significant inadequacy of the mitigation.

5 Other guidelines and recommended practices

In this section

This section describes other guidelines and recommended practices that are desirable to enhance data quality, but are not required for quality coding of data in this Standard.

5.1 Mitigation costs

5.1.1 Background

This Standard provides a method for recording mitigation costs, including descriptions of the attributes to record.

Soil conservation mitigation costs are considered important data for estimating the total expenditure of soil conservation over time. Good quality cost data are useful for estimating the future costs of stabilising remaining highly erodible land, both regionally and nationally.

Recording of soil conservation mitigation costs is currently inconsistent across New Zealand. Authorities receiving funding from the HCEP are required to record cost data, but this is often recorded on a grant-by-grant basis and is not usually based on actual individual soil conservation works. Other soil conservation works outside the HCEP are typically not recorded, or are not available in an easily retrievable format for use in this Standard.[16]

The costing only needs to be an estimate. Rounding costs to the nearest $1000 per hectare for total costs and $500 per hectare for primary category costs should provide sufficient detail. This approach is intended to provide a uniform method for assigning costs that is meaningful at a regional or national scale, enabling a clearer understanding of expenditure, resource allocation and future resource requirements.

5.1.2 Data sources

The most common source of mitigation cost data is provided by the HCEP at the regional programme level. Individual regional authorities may also record cost data for planned or implemented soil conservation work, including vegetation-based mitigations.

For the purpose of this Standard, costs should be assigned (as cost per hectare) to a mitigation polygon within the local land cover layer. The idea is to accumulate the total cost of works over time. If data are available, costs can be broken down further into primary categories:

- afforestation,

[16] NEMS Working Group questionnaire 2024.

- space planting,
- fencing,
- pest and weed control, and
- staff.

Where costs for a farm property spans more than one polygon, or if multiple farm properties are within a single polygon, the cost can be apportioned based on area.

6 GIS Procedures

This Standard requires that the collection and recording of data must follow certain GIS procedures to achieve a quality code of QC 400 to QC 600. The GIS procedures for combining data and data format management in this Standard are provided in **Annex B: GIS Procedures, Templates and Schema**.

7 Reporting

In this section

This section provides a checklist of reporting requirements and a series of statements that are recommended for inclusion when reporting on erodible land and stabilisation mitigations.

7.1 Reporting requirements

When reporting on erodible land, land cover or mitigation data the following must be included:

- Details of the HEL layer version used, and the degree to which HEL was replaced or partially replaced using local data.
- Description of the local data, method and assumptions used.
- The total areas of the local data used.
- The level of certainty applied to the analysis (based on quality coding).
- A description and justification of any areas excluded from the analysis and the influence this may have on the results.
- An explanation of any instances where regional reporting may differ from national reporting when local data have been used to replace the nationally provided HEL data.
- If validation has occurred, an explanation that associated regional reporting may differ from national reporting due to this validation.
- A clear description of the area of interest (region, catchment, etc.), including its boundaries and the inclusion or exclusion of any inshore islands.
- When reporting on change over time, the area (ha) and proportion (%) of change between the start and end dates of the analysis period.
- If administrative boundaries for the areas of interest have changed over time, a description of the change and its impact on comparisons over time.

7.1.1 Reporting on data with varying quality codes

Quality codes are applied to individual polygons within local copies of the data, not to the data set or layer as a whole. A local (vector) copy of data may therefore have several different quality codes. Quality codes are assigned before any conversion to raster data format.

It is recommended that reporting agencies provide additional context on the quality of their data by reporting on the distribution of land area within each quality code. This can be done by tabulating the proportion of land area or polygons that fall into each quality code (i.e. QC 300, QC 400, QC 500, QC 600).

7.1.1.1 Example: Distribution of land area by quality code

The example provided in **Table 13** demonstrates how to report the proportion of land area within each quality code. The classifications on the left reflect key categories relevant to erodible land and mitigation.

Table 13 – Example of how to report the proportion of highly erodible land and stabilised land area within each quality code.

Classification	QC 300	QC 400	QC 500	QC 550	QC 600
National HEL data only	100%	0%	0%	0%	0%
Local HEL data	0%	45%	20%	15%	20%

This approach provides a rough indicator of the accuracy of the reported data. Reporting on data quality should also include a statement confirming that all quality codes from QC 300 to QC 600 are considered adequate for reporting at scales larger than 50 km^2, particularly at national and regional levels of reporting.

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Annex A: Geomorphic Slope Thresholds

Erosion Terrain	Typical Lithology	Slope Threshold	Applicable Regions	Typical LUC Units
Melange or Shattered Rocks	Highly crushed mudstone or argillite	15°	Gisborne, Northland, Marlborough	6e1, 7e1, 8e1 (Shattered types)
Coastal Sandstone	Soft or poorly consolidated sandstone	22°	Taranaki, Manawatū Whanganui, Northland	6e5, 7e5, 7e19
Tertiary Soft rock	Weak mudstone, siltstone, or argillite	24°	Gisborne, Hawke's Bay, Horizons, Taranaki, Wellington, Waikato	6e10 to 6e25, 7e1 to 7e15
Loess or Tephra	Wind blown silt or volcanic ash	26°	Canterbury, Otago, Waikato, Bay of Plenty, Southland	6e1 to 6e4 (Loess), 6e18 (Ash)
Hard rock Hill Country	Greywacke, indurated sandstone, or schist	28°	Wellington, Nelson, Marlborough, Tasman, Otago, West Coast	6e1 to 6e9, 7e1 to 7e8
Mountain Steeplands	Rapidly uplifting alpine zones or axial ranges	45°	West Coast, Canterbury, Otago, Marlborough, Tasman, Wellington	8e1 to 8e6

Annex B: GIS Procedures, Templates and Schema

Overview

This document serves as the GIS annex to the National Environmental Monitoring Standards (NEMS) for Erodible Land and Stabilisation Mitigations. Its purpose is to provide submission standards for GIS data that councils and agencies must follow to ensure regionally and nationally consistent data for reporting and analysis. It details the GIS templates, attribute fields, and data protocols required to achieve certain quality codes in the NEMS for Erodible Land and Stabilisation Mitigations. The goal is to facilitate the creation of quality regional and national databases of erodible land and mitigation efforts.

In this annex, the technical framework for preparing and submitting local highly erodible land (L_HEL) revisions is established. This includes the identification of authoritative data sources, mandatory geodetic standards, and the geoprocessing logic required to maintain spatial integrity. While the procedures described herein are indicative and allow for software-specific flexibility, the final outputs must strictly adhere to the prescribed schemas and quality assurance thresholds to be considered compliant with the Standard.

1 Data standards and metadata

1.1 Authoritative data sources

To ensure data currency, consistency, and integrity, all authoritative national datasets must be sourced directly from the Ministry for the Environment. These essential datasets include the national Highly Erodible Land (HEL) layer, the LCDB, and the Woody Vegetation layer. While the Ministry may refer regional authorities to other agencies, such as the Bioeconomy Science Institute, for technical delivery, the Ministry remains the primary authoritative gateway for these layers.

Local datasets used to refine the national HEL layer must be fit for purpose, spatially accurate, and documented in accordance with the requirements of this Standard

1.2 Geodetic and measurement standards

All spatial data created for reporting purposes must adhere to the mandatory national geospatial standards as defined by Land Information New Zealand (LINZ) or subsequent lead agencies. These currently include the New Zealand Geodetic Datum 2000 (NZGD2000) and the New Zealand Transverse Mercator 2000 (NZTM2000) projection. Coordinates shall be recorded using the official metric Cartesian system. Units of measurement must follow the metric system, with land area recorded in hectares (ha) to two decimal places, or as otherwise specified in the current version of the NEMS Standard.

1.3 Metadata and discoverability

All data created under this Standard should be publicly discoverable and accompanied by metadata that describes its quality and origin. It is recommended that regional authorities utilise a standardised metadata format, such as the Dublin Core set of elements, to ensure long-term verifiability and interoperability. Metadata must, at a minimum, record input datasets and versions, key processing steps, and the specific rules applied for spatial classification and sliver management.

2 Compliance with GIS standards

This section describes the required spatial processing outcomes and logical sequence necessary to produce a compliant local HEL (L_HEL) dataset.

Recognising that individual workflows may vary between regional authorities, this Standard allows for the selection of GIS tools and scripts appropriate to local technical infrastructure, provided the required spatial outcomes are achieved.

Many of the functional processing terms used in this section, such as Union, Dissolve, and Append, refer to standard ArcGIS tools, though equivalent operations in other geospatial software are acceptable provided the final spatial outcomes and attribute schemas are strictly met.

2.1 Spatial overlay and classification

Local erodible land (L_EL) and local land cover and mitigation (L_LC) datasets must be combined using a topology-preserving overlay process, such as a Union operation, that retains the full spatial extent of both inputs.

The output must be segmented so that each polygon represents a unique combination of erosion risk status from the L_EL dataset and mitigation status from the L_LC dataset. Each resulting polygon must then be classified based on the interaction between the erosion risk and the presence of protective woody cover. Under this logic, land is only classified as Highly Erodible Land where a high erosion risk exists in the absence of sustainable protective cover or effective mitigation.

Classification must be based solely on these spatial relationships and must not rely on the deletion or erasure of spatial features, ensuring a complete audit trail of how each final status was derived.

2.2 Attribute assignment and schema compliance

Following the classification process, attributes must be populated using the field names and data types defined in the provided templates and domains. Detailed erosion risk attributes and mitigation details must be transferred from the input layers to the final classified polygons using reproducible processes. All data entry must utilise the standardised domain values defined in Table 4, as this table contains the authoritative codes for classification, quality coding, and mitigation types required by the templates.

2.3 Quality assurance and topology validation

Where adjacent polygons share identical final attributes and classification, boundaries may be simplified using attribute-based aggregation, such as a Dissolve operation, to reduce unnecessary spatial fragmentation.

Mandatory quality assurance and topology validation must be undertaken to ensure the standalone local HEL dataset is mathematically accurate and ready for submission. This validation must involve a formal topology check using rules that prohibit overlapping geometries and ensure spatial continuity within the dataset. Sliver polygons, which are artefacts of processing below the minimum mapping unit, must be managed using documented, rule-based processes and must not be deleted without reassignment or aggregation. These checks are essential for assigning the correct Quality Code to the dataset.

3 Templates and schema

GIS templates have been provided as an Esri file geodatabase with feature classes. The templates can be sourced from the NEMS website using the following link: www.nems.org.nz/tools. The blank templates are for local data for:

- Local erodible land (L_EL)
- Land cover and mitigation (L_LC)
- Local HEL (L_HEL)

The data schema, as described in Tables 4, 5, and 6, represent the single, authoritative reference for the implementation of a Standard-compliant geodatabase for these feature classes.

4 Attribute tables

Standardised attributes are required to ensure data quality, regulatory interoperability, and long-term consistency across regional reporting boundaries. The *GIS annex* mandates specific attribute fields for local erodible land (L_EL), local land cover and mitigation (L_LC), and local HEL (L_HEL) layers.

The attributes are listed with *domains* to provide the exact, standardised values required for data entry. This approach eliminates the need to cross-reference multiple documents, thereby reducing the likelihood of data entry errors and ensuring a high degree of data consistency across different regional agencies. Attributes and their values are applicable to individual polygons.

The schema incorporates fields for tracking not only the core data but also crucial metadata, such as versioning, quality coding, and validation history, which are essential for maintaining the stationarity and verifiability of the dataset over time.

The L_HEL layer must adopt the core data schema used in the national HEL layer, supplemented by the local revision attributes, to ensure seamless national interoperability and reporting consistency, aligning with NEMS conventions.

For this Standard, the required attribute fields required (as provided in the templates) are described in the following tables:

- Table B1 – local erodible land (L_EL) layer
- Table B2 – local land cover and mitigation (L_LC) layer
- Table B3 – local fields additional to those in the national HEL layer for local HEL (L_HEL) layer
- Table B4 – Domains

Table B1 – Fields to include in local erodible land (L_EL) layer

Field Name	Data Type	Domain	Explanation
OBJECTID	Object ID		
Shape	Geometry		
Shape_Length	Double		
Shape_Area	Double		
Area_Ha	Double		
Update_Yr	DateOnly		Year of data revision entry.
Erosion_SEV	Text	Erosion_SEV	Erosion severity assigned at the local level using the LUC Handbook criteria and used in this Standard.
Erosion_TYP	Text	Erosion_TYP	Erosion type assigned at the local level using the erosion types

			defined in this Standard, correlating to the LUC Handbook classification.
Stream_CONN	Text	Stream_CONN	Whether or not erosion is considered connected, or sediment delivered to a stream.
HEL_class	Text	HEL_class	Erosion type that was assigned in the fundamental HEL layer (national layer) (required for consistency and correlation).
Data_SOURCE	Text	DataSOURCE	The general source of the local erodible land attribute (e.g. regional modelled data or mapped LUC).
Imagery_ID	Text		Aerial imagery used for desktop L_EL data.
Imagery_DATE	DateOnly		Date of aerial imagery used for desktop L_EL data.
Data_SCALE	Text	DataSCALE	Approximate scale of the local data (e.g. 1:10,000).
Data_SCALE_other	Text		Scale of the local data if no code in DataSCALE domain.
Validation_TYPE	Text	ValidationTYPE	The general method used for validation of the data.
Validation_DATE	DateOnly		Year the polygon was validated.
Validation_SCP	Text		SCP responsible for undertaking or overseeing the validation.

NEMS_version	Double		The NEMS version at the time of validation.

Table B2 - Fields to include in local land cover and mitigation (L_LC) layer

Field Name	Data Type	Domain	Explanation
OBJECTID	Object ID		
Shape	Geometry		
Shape_Length	Double		
Shape_Area	Double		
Area_Ha	Double		
RevisionYr	Text	Year	Year of data revision entry.
DataSOURCE	Text	DataSOURCE	The general source of the local data for the revision entry.
Imagery_ID	Text		Aerial imagery used for desktop L_LC data.
Imagery_DATE	DateOnly		Date of aerial imagery used for desktop L_LC data.
Data_SCALE	Text	DataSCALE	Approximate scale of the local data for the revision entry (e.g. 1:10,000).
Data_Scale_other	Text		Scale of the local data if no code in DataSCALE domain.
HEL_LCDB_version	Double		LCDB version used in the national HEL layer being revised.
HEL_LCDB_classYr	Text	LCDB_classYR	Year of LCDB classification used in the national HEL layer being revised.
HEL_LCDBclass	Text	LCDB_WoodVegClass	Original LCDB vegetation class used in the national

			HEL layer being revised.
HEL_WL_version	Double		Woody layer version used in the national HEL layer being revised.
HEL_WoodVegclass	Text	HEL_WoodVegClass	Original Woody layer class used in the national HEL layer being revised.
LocalHEL_version	Double		National HEL layer version used for the L_LC.
LocalHEL_LCDBclass	Text	LCDB_WoodVegClass	Revised LCDB vegetation class.
LocalHEL_WLversion	Text	LCDB_classYR	Woody layer version, at the time of the revision entry.
LocalHEL_WLclass	Text	LCDB_classYR	Revised Woody layer class.
MtgtnLC_YOE	Text	Year	Year the mitigation treatment was implemented.
DomMtgtnType	Text	DomMtgtnType	Dominant mitigation attribute present in the polygon (must correlate with NEMS mitigation classes).
DomMtgtnSpGroup	Text	VegSpeciesGrps	General group of land cover or mitigation species (e.g. genus or mixed species category).
Validation_TYPE	Text	ValidationTYPE	Validation method.
Validation_SCP	Text		SCP responsible for undertaking or overseeing the validation.
Validation_YEAR	Text	Year	Year the L_LC polygon was validated.

Validation_ImgID	Text		Aerial imagery used for desktop validation.
Validation_ImgYr	Text	Year	Date of aerial imagery used for desktop validation.
Validation_NEMSvrsn	Double		The NEMS version at the time of the L_LC validation.
MtgtnQA_DATE	Text	Year	Year of mitigation quality assessment.
MtgtnQA_TYPE	Text	ValidationTYPE	The general method used for mitigation quality assessment for the L_LC polygon.
MtgtnQA_ImgID	Text		Aerial imagery used for mitigation assessment.
MtgtnQA_ImgDATE	DateOnly		Date of aerial imagery used for mitigation assessment.
MtgtnQA_NEMSvrsn	Double		NEMS version at the time of the L_LC mitigation quality assessment.
MtgtnQA_SCP	Text		SCP responsible for undertaking or overseeing the mitigation quality assessment.
MtgtnQA_STAGE	Text	EstabStage	Stage of establishment at the time of mitigation quality assessment.
MtgtnQA_APPRTNSS	Text	Assessment	Mitigation appropriateness as defined in this Standard.
MtgtnQA_CnpyCov	Text	CanCover%	Estimated canopy cover of mitigation (percentage).
MtgtnQA_BareGrnd	Text	BareGrnd%	Estimated bare ground of land

			cover or mitigation (percentage).
MtgtnQA_EFFECTNSS	Text	Score Classes	Mitigation effectiveness classification defined in this Standard.
MtgtnQA_QualCLASS	Text	Score Classes	Mitigation quality classification defined in this Standard.
Mtgtn_COSTperHa	Double		Total estimated cost of mitigation (to the nearest $1000 per hectare).
Mtgtn_COSTsource	Text	CostSource	Source of the cost data (e.g. HCEP, regional council).
Mtgtn_COSTstatus	Text	CostStatus	Status of the mitigation work.
AfforestationCOST	Double		Estimated cost of afforestation works recorded to the nearest $500.
SpacePlantCOST	Double		Estimated cost of space planting works recorded to the nearest $500.
FenceCOST	Double		Estimated cost of fencing works recorded to the nearest $500.
ControlCOST	Text	CostControlTypes	Estimated cost of pest and weed control recorded to the nearest $500.
StaffCOST	Double		Estimated staff time cost (hours x rate) for administering the work, rounded to the nearest $500 per hectare.
SubsidyRATE	Double		The subsidy rate for the mitigation activity as a percentage.

Costing_NEMSvrsn	Double		The NEMS version at the time of the costing.
NEMS_version	Double		

Table B3 – Fields to include in the local HEL (L_HEL) layer

Field Name	Data Type	Domain	Explanation
OBJECTID	Object ID		
Shape	Geometry		
Shape_Length	Double		
Shape_Area	Double		
EL_RevSTATUS	Text	Review Status	Indicates if a change to the polygon has occurred.
EL_RevDATE	DateOnly		The year the L_EL change was recorded.
EL_RevMETHOD	Text		Source and method for L_EL data.
EL_HELclass	Text	HEL_class	The revised HEL fundamental erodible land class.
EL_ValDATE	DateOnly		Date the L_EL was validated.
EL_ValMETHOD	Text		L_EL validation method.
EL_Val_SCP	Text		SCP responsible for undertaking or overseeing the validation.
LC_RevSTATUS	Text	Review Status	Indicates if a change to the polygon has occurred.
LC_RevDATE	DateOnly		The year the L_LC change was recorded.

LC_RevMETHOD	Text		Source and method for L_LC data.
LC_Val_SCP	Text		SCP responsible for undertaking or overseeing the validation.
LC_DomMtgtn	Text	DomMtgtnType	Dominant mitigation present in the polygon (must correlate with NEMS mitigation classes).
LC_LCDBclass	Text	LCDB_WoodVegClass	LCDB vegetation class used in the local land cover layer (L_LC).
LC_WL_Class	Double		Woody layer class used in the local land cover layer (L_LC).
LC_ValDATE	DateOnly		Date the L_LC polygon was validated.
LC_ValMETHOD	Text		L_LC validation method.
LC_MtgtnQA_DATE	Date		Date of mitigation quality assessment.
LC_MtgtnQA_METHOD	Text		Method of mitigation quality assessment.
LC_MtgtnQA_SCP	Text		SCP responsible for undertaking or overseeing the assessment.
LC_Mtgtn_APPRTNSS	Text	Assessment	Mitigation appropriateness as defined in this Standard.
LC_Mtgtn_EFFECTNSS	Text	Score Classes	Mitigation effectiveness classification defined in this Standard.
Mtgtn_COSTperHa	Double		Total estimated cost for mitigation (to the nearest $1000 per hectare).

COSTsource	Text	CostSource	Source of the cost data (e.g. HCEP, territorial authorities).
COSTdate	Text	Year	Date the cost data were recorded.
COSTstatus	Text	CostStatus	The status of the mitigation work.
COST_NEMSvrsn	Double		The NEMS version at the time of the costing.
QualityCode	Text	QCcodes	Quality code (used in this Standard).
Reg_HELversion	Text		Version number of the national HEL layer used as the base for the local revision.
Reg_HELclass	Text	HEL_class	Local HEL classification.
Reg_LCDBclass	Text	LCDB_WoodVegClass	Local LCDB classification.
Reg_LCDBclassYR	Text	LCDB_classYR	Local LCDB classification year.
NEMS_version	Double		As located on the cover of the Standard utilised at the time quality coding was assigned.

Table B4 – Domains

Domain Name	Description	Code
Assessment	Mitigation appropriateness score	Appropriate
		Not appropriate
		N/A
Bareground%	Estimated bare ground as percentage	N/A
		<1%

		1<2%
		2<5%
		5<10%
		10%>
CanCover%	Estimated canopy cover as percentage	N/A
		0<25%
		25<50%
		50<75%
		75-90%
		90-100%
CostSource	Source of cost data	HCEFP
		Territorial Authority
		Regional Council
		Contractor
		Landowner
		Other funder
		N/A
CostStatus	Status of mitigation work	In progress
		Completed
		N/A
CostControlTypes	Types of control methods	Pest
		Weed
DataSCALE	Scale of local data mapping	1:1,000

		1:2,000
		1:5,000
		1:7,500
		1:10,000
		1:15,000
		1:20,000
		1:30,000
		1:40,000
		1:50,000
		1:75,000
		1:100,000
		see Other
DataSOURCE	Source of local erodible land attribute	Modelled
		Mapped-Aerial imagery
		Mapped-Farm plan LUC
		Land cover layer
		Other
DomMtgtnType	Predominant mitigation types present in polygon	Spaced trees (Standard)
		Spaced trees (Close)
		Native forest (Planted)
		Native forest (Rev/Ret)
		Exotic plantation forest
		Exotic continuous-cover forest
		N/A

Erosion_SEV	Erosion severity classes	Neglible (0)
		Slight (1)
		Moderate (2)
		Severe (3)
		V. severe (4)
		Extreme (5)
		N/A
Erosion_TYP	Erosion type	Soil slip
		Earthflow
		Gully
		Slump
		Other
		N/A
EstabStage	Years since establishment. Used for Mtgtn QA	0-1
		2-5
		6-10
		11-15
		>15
		Uknown
HEL_class	Erosion type assigned in national dataset	High LS risk/stream delivery
		High LS risk/non-stream delivery
		Moderate EF risk
		Severe EF risk
		Gully risk

HEL_WoodVegClass	Original HEL woody layer codes	1
		2
		3
		4
		5
		6
		7
		N/A
LC_Method	Source of Local land cover info	Modelled
		Mapped
		Desktop
		On ground
		Aerial imagery
		LiDAR
LCDB_classYR	Assessment years used in LCDB classifications	2023
		2018
		2012
		2008
		2001
		1996
LCDB_WoodVegClass	LCDB woody vegetation classification	2
		33
		47
		51

		52
		54
		55
		56
		58
		68
		69
		70
		71
		N/A
QCcodes		QC200
		QC300
		QC400
		QC500
		QC550
		QC600
Review Status		Revised
		No changes
		N/A
Score Classes	Effectiveness/Quality score	High
		Moderate
		Low
		N/A
Stream_CONN		Connected

	Stream connectivity status of erosion feature	Not connected
ValidationTYPE	Method used for validation of data	Desktop
		On ground
		Combination
		Not validated
VegSpeciesGrps	General land cover species groups	Poplar sp.
		Willow sp.
		Poplar/Willow (mix)
		Pine sp.
		Other exotic sp. (single)
		Other exotic sp. (mix)
		Manuka
		Other native sp. (single)
		Other native sp. (mix)
		Native/Exotic (mix)
		Unknown
		N/A
Year	Year in yyyy format	2025
		2026
		2027
		2028
		2029
		2030
		2031

		2032
		2033
		2034
		2035

4.1 Version control and archiving

Either the addition of fields into the attribute table of the local copy of the HEL layer or 'versioning' are acceptable methods for version control.

It is recommended that agencies have only one local copy of the HEL layer that is treated as the final version at any given time stamp for the purposes of reporting and sharing externally; and that a 'bulk update' process is undertaken from the working copy to the local copy of the HEL layer at regular intervals or as required for reporting purposes.

At the time a new version of the national HEL layer is released by Bioeconomy Science Institute[5] (or any other future holder of the HEL model), a manual update to local copies of the HEL layer will be required.

It is highly recommended that all versions of local copies are archived. If data storage is restricted and it is not possible to keep all versions, it is recommended a rolling archive is maintained such that the most recent versions are retained and the oldest versions are replaced with newer versions as dictated by the available storage space. Where it is not possible to retain versions, shapefiles should be created and these archived.