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Waikato Prioritisation Framework and its use for soil conservation – development and methods

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Table of Contents

Figures

Tables

Abbreviations

CLUES	Catchment Land Use for Environmental Sustainability model
GIS	Geographic Information System
HEL	Highly Erodible Land
ICM	Integrated Catchment Management
LCDB	Land Cover Database
LCDB v5.0	Land Cover Database 5.0
LTP	Long Term Plan
LUC	Land Use Capability
N	Nitrogen
NIWA	National Institute of Water and Atmospheric Research
NZeem®	New Zealand empirical erosion model
NZLRI	New Zealand Land Resource Inventory
P	Phosphorus
REC	River Environment Classification
RPS	Regional Policy Statement
SAS	Science and Strategy group
SQL	Structural Query Language
WRC	Waikato Regional Council
WPF	Waikato prioritisation framework
WRP	Waikato Regional Plan
WWRRS	Waikato and Waipā River Restoration Strategy

Abstract

The Waikato Prioritisation Framework (WPF) comprises a series of components and geospatial processes that collectively are used to simplify the use of data from multiple models. This tool can be applied to a region or sub-catchment to show locations with high to low risk for soil conservation, water quality, or biodiversity factors. The methods employed are flexible enough to allow adjustments to be made spatially (for example by catchment management zone) or temporally (as improved input data becomes available) while retaining a consistent geospatial approach.

The WPF provides a single decision support tool for consistent prioritisation across catchments and provides increased efficiency for targeting resources used in mitigations. The WPF can be used for several spatial prioritisation applications (e.g. soil conservation, water quality, or biodiversity).

This report describes the use of the WPF for soil conservation. It covers using the framework to show soil conservation risk locations, and its ability to apply general soil conservation mitigations used by WRC to estimate the cost of the mitigations and estimate the impact of mitigations on reducing water contaminants (sediment, nutrients, and *E. coli* bacteria). Collectively, the outputs provided assist with decision making around soil conservation work programmes for WRC and others.

Executive summary

Introduction
This report describes the methods used to develop the Waikato Prioritisation Framework and its use for making soil conservation management decisions. The Waikato Prioritisation Framework (WPF) has been developed through the Waikato Regional Prioritisation Project (WRPP) at Waikato Regional Council (WRC). It is a spatial framework that utilises spatial model data from multiple sources and applies geospatial techniques for determining priorities based on risk. The WPF can be used for a number of spatial prioritisation projects. In this report, the framework has been used to determine soil conservation priorities, mitigation costs, and their estimated impact on water quality improvement. The degree of risk, and its location in the catchment, can be used to guide decision making for implementing soil conservation mitigations and achieving improvements in water quality. It provides a decision support tool for consistent prioritisation across catchments, identifying locations with the greatest potential for water quality improvement, and increasing the efficiency of implementing soil conservation resources.

Background of the Waikato Prioritisation Framework
In 2013, Waikato Regional Council's sustainable land management programmes highlighted a need to improve the way the Council prioritised, and connected catchment works (soil conservation, river management, and biodiversity) within and across catchment management zones in the region.

Previous prioritisation approaches used in the Waikato region for soil conservation planning and implementation generally used a simple level of spatial prioritisation based on one static dataset showing the location of high to low risk. Often the outputs were difficult to interpret because of the wide spatial scatter of the high values at sub-catchment scale.

Over the 2013/14 year, an improved spatially-based prioritisation framework was developed for the Waipā catchment to support the implementation of integrated catchment management in that zone. The new framework was an improvement on the previous prioritisation method. A similar improved framework was proposed for the rest of the Waikato Region, and development of the Waikato Prioritisation Framework (WPF) commenced. The WPF has been incrementally improved since 2013/14 to meet new specific needs of WRC soil conservation programmes.

Methods
The Waikato Prioritisation Framework utilises a series of components and geospatial processes that collectively simplify multiple model data and increase the accessibility of the data to a broader and more diverse audience, while remaining science-based. The methods employed are flexible enough to allow adjustments to be made spatially (for example by management zone) or temporally (as improved input data becomes available) while retaining a consistent geospatial approach. A summary of the Waikato Prioritisation Framework components are as follows:

Component	Description
Framework base	Spatial analysis base consisting of reach-watersheds derived from REC2, combined with a regional land use layer overlay.
Datasets and metrics	Available regional and national spatial model datasets.
Factors (risks)	Soil conservation and water quality factors (risks) considered important by WRC and linked to soil conservation mitigations that WRC implement.
Key issues	Individual factors are combined to address the key issues of soil conservation and related water quality risks.
Scoring and ranking	Relative risk scores are generated for all factors. For key issues, individual factors are combined, and weighted relative (risk) scores are estimated for each key issue. Relative risk scores are used to rank and prioritise areas.

Mitigations	Soil conservation related mitigations are identified.
Costs	Costs for implementing soil conservation mitigations are estimated.
Reductions	Reductions in water contaminants resulting from soil conservation mitigations are estimated for sediment, nitrogen, phosphorus, and microbes.
Decision support outputs	Graphed relative scores and maps for a selected area which can range in size from region to sub-catchment.

The Waikato Prioritisation Framework is underpinned by two key spatial tools. These are the regional hydrological network and regional land use. The hydrological framework uses the River Environment Classification, v2.5 (REC2), (NIWA, 2021). The main advantages of using the REC2 are that (i) it provides hydrological connectivity, (ii) models such as the Catchment Land Use for Environmental Sustainability model (CLUES) use the REC river segments to perform their calculations (Elliot et. al., 2016), (iii) it can be spatially aggregated to interrogate data at various scale, and (iv) it provides full regional coverage. The land use layer in the WPF is based on the methods used for the CLUES land use layer but has been rebuilt to include more current land cover (LCDB v5.0) and land use (2018 Agribase) data.

Key issues are those that have been identified in consultation with WRC staff and are addressed through implementing mitigations as part of WRC soil conservation work programmes. Essentially the key issues are treated as geospatial sub-models within the framework. These sub-models can be revised, or new models added to provide prioritisation guidance for specific issues as required. For each key issue, the individual factors contributing to the issue are identified and combined. Factors (risk scores) are weighted (as a percentage contribution to the total key issue score) based on their perceived relative contribution (or importance) to the key issue, and scores for the key issue are calculated.

Factors are those aspects which contribute to creating a key issue. For example, factors relating to soil conservation are, erosion of hillslopes, runoff of sediment from the land, lack of riparian fencing allowing stock to access streambanks and reduced streambank stability. For each factor, a metric is used to calculate a factor score, which in turn are combined and used to calculate scores for key issues. Individual factors are represented by a metric, which is an attribute provided by one or more of the spatial models used to input data for the framework.

The WPF approach is to combine all available model data to utilise each model's strengths and simplify the combined data for easier interpretation for use. Additionally, as models are revised, or new models become available, they can be incorporated into the WPF for use.

For each dataset, simple metrics have been selected to inform the factors identified. Metrics are generally area, length, or yield-based. The current WPF utilises 13 main datasets or models.
The WPF provides for spatial analysis at multiple scales. This is enabled by the contiguous hydrological framework on which the spatial analysis is based. To provide the flexibility WRC requires for decision making and mitigation implementation, the finest scale units (REC2 reach-watersheds) can be aggregated into WRC defined sub-catchments and management zones.

The Waikato region comprises eight management zones which are managed independently. The use of management zones recognises the variation in geology, topography, and soil conservation-related issues across the region. Collectively, the eight management zones are further delineated into 354 sub-catchments. The sub-catchments have been derived for each management zone through consultation with WRC staff. These are generally sub-catchments that are familiar to WRC staff and community groups, and where works are, or have been, undertaken.

The WPF uses relative normalised scores which are calculated for all reach-watersheds. The geospatial analysis to calculate these scores uses MANIFOLD® GIS software and SQL language to write scripts to automate and speed up the analysis. This allows the analysis to be updated regularly if changes are required, or input datasets are modified or added. The analysis computes a score for each reach-watershed. The final scores are normalised to enable the combination and comparison of factors across the catchment.

Additionally, data are normalised where multiple datasets are used to derive a factor score (e.g. CLUES sediment and SednetNZ can both be used to derive the sediment factor score). This approach allows data of different scales to be aggregated to derive a single risk score. The final factor score for a reach-watershed has two components: a *reach score* and an *upstream score*.

The *reach score* is derived using the proportion of the threat that occupies the reach-watershed. It represents the factor's contribution from the reach-watershed. An *upstream score* component is included to reflect the impact/contribution of the upstream catchment above a reach-watershed. Also, this has the effect of "averaging" the scores in closer proximity (in a hydrological context) to simplify the visual pattern shown in the prioritisation outputs. The *upstream score* is derived by averaging all upstream reach-watershed scores for every reach-watershed.

The final reach-watershed factor score is derived by summing the *reach score* and *upstream score* for each reach and scaling the result to yield a normalised score scaled from 0-100:

Reach-watershed factor score =

((Reach score + Upstream score) / Max (Reach score + Upstream score)) * 100

The ranking of scores for individual factors and combined factors (key issues), mitigation costs and reductions requires that the data be normalised across attributes to provide relativity in the scoring and ranking analysis. This has the following advantages:

- allows the bringing together of multiple datasets,
- provides flexibility to incorporate new data as it becomes available,
- it is hydrologically connected,
- consideration of the upstream catchment condition and inclusion in the score for a reach-watershed, and
- it is scalable to provide information and a framework for whole of catchment and sub-catchment scale assessment.

For individual factors and mitigations, the ranking is based on the normalised score for the reach-watershed. For key issues, the ranking is based on the weighted score sum of all contributing factors.

Soil conservation mitigations

The inclusion of soil conservation mitigations aims to identify actions that can be used by land managers to address soil conservation and related water quality issues for a given area. The inclusion of the mitigations provides a way of estimating the "catchment scale" efficacy, in terms of reducing risks, and the cost of doing so.

A suite of six soil conservation mitigations have been developed for the WPF. However, for each management zone these may be revised based on specific soil conservation practices developed in each zone. There are two riparian management mitigations and four hillslope mitigations. The riparian mitigations are based on the level of riparian protection provided by fencing (to exclude stock), and woody vegetation (to increase soil stability provided by tree roots). Three of the hillslope management mitigations are based on land limitations as indicated by the Land Use Capability (LUC) sub-class, and one is based on the presence of active erosion. All six mitigations are implemented by WRC in their catchment works programmes.

Not all mitigations should be placed everywhere in the catchment. Mitigation placement is limited to the areas which are realistic for placement and which target risks. Estimating where mitigations can be placed, their cost, and relative effectiveness of water contaminant reductions, will assist with prioritising actions in the catchment.

Mitigation cost estimates are based on those used for the Waikato and Waipā River Restoration Strategy but are reviewed for each management zone as required. The review process involves workshops with WRC staff, land managers and can include community representatives.

The WPF has developed water contaminant reduction estimates for the six soil conservation mitigations. Reduction estimates are for sediment, nitrogen, phosphorus, and faecal microbes entering waterways. Reduction estimates are based on available literature.

For all mitigation related estimates there is a high level of uncertainty around the mitigation reductions that can be achieved. This is primarily because of variable local conditions, farm management practices, and implementation effectiveness.

In the WPF, the soil conservation mitigations focus on general actions such as fencing and planting. However, several site-specific mitigations such as detainment bunds, bridges, and constructed wetlands are also included.

Scale and uses

The WPF database can be interrogated to produce outputs at various scales; for whole of catchment, sub-catchment, and individual reach-watersheds. The WPF output formats include graphs and static maps. The outputs were developed in consultation with WRC staff to provide simple to understand information for a broad audience. This is an important consideration for ensuring science is accessible for all those involved in WRC catchment work programmes.

One of the main features of the map outputs is their visual representation of the data. The colour ramps used are adjusted to the scale of the area of interest by recalculating the data to present as relative normalised scores for only the reach-watersheds in the area of interest. This could be for the entire region, or a specific sub-catchment. This provides a visual relative normalised representation of the data which allows for easier visual interpretation. Additionally, graphed data are treated the same and correlate with the map data.

WRC has used the WPF (through the Waikato Regional Prioritisation Project) for numerous activities, primarily for catchment management, prioritisation, and planning. Examples of its use include:

- Informing catchment management
    - Catchment and Zone Management Plans
    - Implementing soil conservation and river management works
    - Identifying Priority catchments
    - Coromandel Focus Catchments
    - Prioritising West Coast harbour catchments
- Waikato and Waipā River Restoration Strategy
- Supporting funding applications
    - Waikato River Authority (Waikato River Clean-up Trust)
    - One Billion Trees Programme
    - Hill Country Erosion (HCE) Programme
- Informing policy
    - Healthy Rivers Wai Ora (Plan Change 1) Catchment Stories
- WRC related projects
    - Waipā Afforestation Feasibility Study

A worked example shows how the WPF is used for a West Coast management zone sub-catchment prioritisation assessment. It should be noted the example is illustrative only and the data provided may differ from any actual assessment for the West Coast.

Conclusions

- The Waikato Prioritisation Framework (WPF) has been developed incrementally since the 2013/14 year through the Waikato Regional Prioritisation Project (WRPP) at Waikato Regional Council (WRC).
- The WPF is primarily used by Waikato Regional Council, but is of benefit to iwi partners, the Waikato River Authority, Co-governance partners, and land managers, funding agencies, and communities within the wider Waikato region.
- The WPF combines multiple sourced spatial model data and applies geospatial analysis techniques to derive prioritisation rankings (scores) for managing soil conservation, at multiple scales, across the Waikato region.
- The Waikato Prioritisation Framework is dynamic in nature, providing the flexibility to adjust spatial model data inputs and criteria as new data becomes available, or as soil conservation related priorities change throughout the region.
- The WPF (and its geospatial analyses) are underpinned by a hydrologically contiguous framework and current land use layer. These ensure regional consistency in the analyses and allow for aggregation of data at different spatial scales.
- The WPF can be used to inform soil conservation works at a sub-catchment scale by identifying locations of highest risk and greatest potential opportunity for focusing and prioritising soil conservation work programmes.
- Individual factors relating to soil conservation are identified and metrics used to assign relative normalised factor scores to reach-watersheds. These factor scores can be ranked to indicate relative risks associated with the individual factors.
- Factors can be grouped to represent key issues. Three key issues have been developed for the WPF, of which two (soil conservation and water quality) are currently being used. The third issue (biodiversity) is under revision.
- Soil conservation mitigations used by WRC work programmes have been developed and can be imposed onto the WPF. A suite of six mitigations have been developed, two for riparian management, and four for hillslope management.
- Inclusion of the mitigations enables mitigation resources and costs to be estimated for areas of interest such as sub-catchments and management zones.
- Available research literature has been used to develop estimates of the likely sediment, nitrogen, phosphorus, and faecal microbe reductions achieved when implementing mitigations.
- Various data outputs are used for communicating the results of the WPF analyses. These are visually focused to enable easy interpretation by a broad audience including WRC, land managers, and the community.
- The main WPF outputs include maps, graphs, and tables, which can combine and represent the output data to guide soil conservation decision making.
- WPF outputs have been used in numerous soil conservation projects at WRC since 2013/14 and provided data to support various funding applications for soil conservation.
- The WPF is flexible to allow iterative revisions as new input datasets/models become available, or as the focus of WRC soil conservation programmes change.

Future developments

- Incorporating new biodiversity data back into the WPF and developing a revised biodiversity key issue,
- investigating the inclusion of newly available spatial data into the WPF, and
- periodically revising the WPF (every three to five years) to incorporate new data rather than as it becomes available.

1 Introduction

This report describes the methods used to develop the Waikato Prioritisation Framework (WPF) for soil conservation. The Waikato Prioritisation Framework has been developed through the Waikato Regional Prioritisation Project (WRPP) at Waikato Regional Council (WRC). It is a spatial framework that utilises spatial model data from multiple sources and applies geospatial techniques to provide a relative risk-based spatial framework for determining priorities to guide decision making. The WPF can be used for a number of spatial prioritisation projects. In this report the framework has been used to determine soil conservation priorities, their mitigations and expected water quality improvements. The Waikato Prioritisation Framework provides a single decision support tool for consistent prioritisation across catchments and increased efficiency of implementation of soil conservation resources.

The Waikato Prioritisation Framework has been developed incrementally since the 2013/14 year to inform soil conservation related works that are carried out via management zone and catchment management plans in the Waikato Region. The WPF informs soil conservation works at a sub-catchment scale by identifying locations of highest risk and greatest potential opportunity for focusing and prioritising work programmes for soil conservation and their water quality improvements. Although the WPF is primarily used by Waikato Regional Council, it is of benefit to iwi partners, the Waikato River Authority, Co-governance partners, land managers, funding agencies, and communities within the wider Waikato region.

The objectives for the project were:

1. Develop for use, a preliminary regional spatial framework to inform the prioritisation of soil conservation, biodiversity, and water quality mitigation implementation at a catchment scale.
2. Provide maps and associated data to inform prioritisation decisions (a decision support system).
3. Include peer review to provide scientific certainty for the spatial framework.

Previously, WPF processes and application have been documented in internal reports, covering part of the development of the methods. The purpose of this report is to provide WRC with a consolidated, up-to-date, and externally available reference detailing the methods used to develop the Waikato Prioritisation Framework. It should be noted that with respect to framework outputs, the report only focuses on specific examples for the purpose of method explanation (with a focus on West Coast outputs), rather than including all region wide outputs.

2 Waikato Prioritisation Framework

2.1 Introduction

Although a complex statistically based model could be used to do what the Waikato Prioritisation Framework aims to achieve, the framework approach presented in this report has the advantage of using simple empirical methods and hydrological spatial aggregation.

The framework uses a collection of geospatial analytical approaches and spatial analyst skills under direction of land scientists and land management practitioners. Visual spatial outputs and associated data table summaries are provided as tools to assist decisions on priority locations for undertaking land management activities. The WPF can be used for several spatial prioritisation applications (e.g. soil conservation, water quality, or biodiversity).

2.2 Objectives

The initial objectives identified for the Waikato Prioritisation Framework for soil conservation included:

- build a regional framework to produce a regionally consistent spatial picture of catchment soil conservation issues,
- use catchments provided by on-ground staff for each management zone to rank catchments according to soil conservation issues,
- determine the optimal aggregations of watersheds within catchments to help prioritise mitigations, and
- identify potential priority catchments regionally, and for each management zone.

2.3 Framework overview

The Waikato prioritisation framework combines multiple sourced spatial model data and applies geospatial analysis techniques to derive prioritisation rankings (scores) for managing soil conservation, water quality, and eventually biodiversity, at multiple scales across the Waikato region. The hydrological and land use frameworks provide the "base" on which multiple spatial model data are imposed for the various spatial analyses to create the outputs used for prioritisation.

The Waikato Prioritisation Framework is dynamic in nature, providing the flexibility to adjust spatial model data inputs and criteria as new data becomes available, or, for example, as soil conservation related priorities change throughout the region.

2.4 WPF development phases

In 2013, Waikato Regional Council's sustainable land management programmes highlighted a need to improve the way Council prioritised, and connected catchment works (soil conservation, river management, and biodiversity) within individual management zones, and consistently across management zones, in the region.

Previous prioritisation approaches used in the Waikato region for soil conservation planning and implementation generally used a simple level of characterisation based on one static dataset showing the location of high to low values. Often the outputs were difficult to interpret because of the wide spatial scatter of the high values at sub-catchment scale. Commonly only one model or one main factor was used to determine catchment priorities. For example, for determining soil conservation implementation for Project Watershed[1] only New Zealand Land Resource

[1] Project Watershed was undertaken in the early 2000s to develop a consistent framework for managing and funding flood protection, soil conservation, and river management in the greater Waikato River catchment.

Inventory (NZLRI) Land Use Capability (LUC) classes 6e, 7 and 8, as well as land cover (as determined at the time by the Land Cover Database 1 − LCDB1) and 1:50,000 scale hydrology, were applied to assess implementation locations and resource requirements. In addition, the identification of priority catchments for implementing work programmes was unclear and inconsistent across management zones in the region.

Over the 2013/14 year, a spatially based prioritisation framework was developed for the Waipā catchment to support the implementation of integrated catchment management in that zone. The prioritisation framework (as part of a broader prioritisation process) helped to identify priority sub-catchments and sites for soil conservation, water quality (nutrients), and biodiversity. The outputs of the Waipā framework have informed the priority catchment management approach in the Waipā Catchment Plan (Waikato Regional Council, 2014).

Following the development of the WPF for the Waipā Catchment Plan, the Waikato Regional Prioritisation Project (WRPP) was initiated, proposing a similar framework for the rest of the Waikato Region. The project had an initial framework development phase (**Phase 1** – "Waikato Lite") which ran through 2014/15 using existing regional data sets (Hill et al., 2015). Phase 1 was intended to provide all management zones with initial information on broad priorities. Following Phase 1, second and third phases of the project were indicated in the Waikato Regional Council's Long Term Plan.

Phase 2 (2015/16 to 2016/17) incorporated new model data and updates to the framework identified in an external peer review of the WRPP in Phase 1 (Hill and Borman, 2016). Phase 2 only covered the greater Waikato Catchment zones of Waipā, Upper Waikato, Central Waikato, and Lower Waikato. This was part of the development of the Waikato River and Waipā River Restoration Strategy (Neilson et al., 2018a).

The development of mitigations for soil conservation, including estimates of mitigation costs and sediment reductions resulting from the spatial implementation of the mitigations, were a feature of Phase 2.

Phase 3 built on the revised prioritisation framework used for the Waikato River and Waipā River Restoration Strategy with new model data and updates and was completed for all catchment zones in the Waikato Region in 2020/2021.

It should be noted that biodiversity has not been included in the WPF since Phase 1 as the prioritisation methods have been in a process of incremental revision across the region. It is intended that once complete, the biodiversity prioritisation model will be reincorporated into the framework.

The incorporation of SedNetNZ model data for the whole region, a revised land use layer, and soil conservation mitigations for the whole region (including estimates of mitigation costs and sediment reductions) were a feature of Phase 3.

2.5 Key issues

Key issues are those identified in consultation with WRC staff and are addressed through implementing mitigations (e.g. as part of WRC soil conservation related work programmes). Essentially the key issues are the geospatial sub-models within the WPF. These sub-models can be revised, or new models added to provide prioritisation guidance for specific issues as required. For each key issue, the individual factors contributing to the key issue are identified and combined. Factors (risk scores) are weighted on their perceived relative contribution (or importance) to the key issue, and scores for the key issue are calculated.

There are three key issues identified in the WPF. These are soil conservation, water quality, and biodiversity (in progress). Currently, only the soil conservation sub-model is fully developed and being used within the WPF. The water quality key issue sub-model is partially complete but has yet to have water quality mitigations developed and implemented. At present the water quality risk outputs can be used in conjunction with the soil conservation key issue sub-model to indicate where water quality risks may be greater. The biodiversity key issue sub-model developed for the Waipa Catchment Plan (WRC, 2014) and the rest of the region (Hill et al., 2015) has since been undergoing an incremental revision across the region and as such is not currently included in the WPF. On completion of the regionally revised biodiversity data, it is envisaged that the biodiversity sub-model will be incorporated into the WPF.

An important concept of the WPF, is the use of individual factors and the identification of key issues. In combination they allow for specific setting of priorities across catchments. For example, priority catchments may be different for different key issues; high N nutrient catchments may be different to erosion risk priority catchments which, in turn, may be different to biodiversity priority catchments (WRC, 2014).

For each key issue, the factors relevant to the key issue are selected and their contribution to the key issue score weighted to reflect their relative importance. Weightings are largely based on expert opinion and in consultation with WRC staff. They can be adjusted in the future as required if supporting information becomes available.

In this report the methods for the soil conservation key issue are described in detail. The detailed methods for the water quality and the biodiversity key issues will be covered in separate reports.

2.6 Scoring and ranking

The WPF uses relative normalised scores which are calculated for all reach-watersheds. The use of relative normalised scores has both advantages and disadvantages when compared with using absolute data.
The main **advantages** include:

- data is averaged across model outputs for risks, this can reduce the influence of extreme outlying data,
- being able to combine data from multiple output sources (i.e. data from multiple models) to create a single “score” that represents the average of all the model data used – this reduces the reliance on a single model (all models have strengths and weaknesses),
- being able to combine multiple threats, and weight the scores to address a specifically defined catchment value,
- enabling a relative comparison of the effectiveness of different mitigations, and
- aggregation of reach-watersheds into sub-catchments and catchments to identify threats and effectiveness at multiple scales.

The main **disadvantages** include:

- data is averaged across model outputs for a risk, this can lead to loss of the “high and low” extremes within data that may be important − for example most contaminants move through a catchment at high flows, and if so, averaging the data across ‘contradictory’ model outputs effectively normalises the data, and
- only relative percentage changes can be estimated for threats and mitigations − estimates of absolute yield cannot be calculated.

2.7 Spatial scales

The WPF provides for spatial analysis at multiple scales. This is enabled by the contiguous hydrological framework on which the spatial analysis is based. To provide the flexibility WRC require for decision making and mitigation implementation, the finest scale units (reach-watersheds) which have an average area of about 26 ha, can be aggregated into WRC defined sub-catchments and management zones.

The Waikato region comprises eight management zones which are managed independently. The use of management zones recognises the variation in geology, topography, and soil conservation-related issues across the region.

Sub-catchments in the WPF have been derived for each management zone through consultation with WRC staff. These are generally sub-catchments that are familiar to WRC staff and community groups, or where works are or have been undertaken. The named catchments serve several main purposes including, (i) provide some geographic familiarity, (ii) test how any existing priority catchment works sit relative to the outputs of the WPF, and (iii) provide a means by which the location of priorities (to inform plans) can be communicated. They are of a size that matches local catchment groups, about 10,000 ha in size. Sub-catchments are assigned a name (i.e. sub-catchments are referred to as "named catchments"). The naming of the sub-catchments is usually based on the main stream or river in the sub-catchment and acts to provide some local familiarity to both WRC staff and catchment landowner, especially when interpreting the WPF output maps and data. A summary of the current number of sub-catchments for each management zone used in the WPF is provided in Table 1.

Table 1. Sub-catchment count and mean area by management zone.

Management zone	Sub-catchment count	Sub-catchment mean area (ha)
Central Waikato	10	5981
Coromandel	22	8248
Lake Taupo	44	6222
Lower Waikato	38	7709
Upper Waikato	52	7575
Waihou Piako	28	14037
Waipa	36	8588
West Coast	32	11580
Waikato region	262	8743

An important point to note is that the framework does not use the named catchments in its analysis. Ideally, the outputs from the framework can be used to simply show the relative reach-watershed scores and where clusters of similar scores occur within the reach. The named catchments can be imposed on the framework watersheds to show their relative reach-watershed scores and where clusters of similar scores occur. This is useful for focussing efforts within existing named catchments.

2.8 Applications

WRC has used the WPF (through the Waikato Regional Prioritisation Project) for numerous projects, primarily for catchment management prioritisation and planning. Examples of its use include:

- Informing catchment management
    - Catchment and Zone Management Plans
    - Implementing soil conservation and river management works
    - Identifying Priority catchments
    - Coromandel Focus Catchments
    - Prioritising West Coast harbour catchments

- Waikato and Waipā River Restoration Strategy
- Supporting funding applications
    - Waikato River Authority (Waikato River Clean-up Trust)
    - One Billion Trees Programme
    - Hill Country Erosion (HCE) Programme
- Informing policy
    - Healthy Rivers Wai Ora (Plan Change 1) Catchment Stories
- WRC related projects
    - Waipā Afforestation Feasibility Study

Details of these WPF applications are provided in a review of the Waikato Regional Prioritisation Project by Hill (2021). In addition to guiding annual soil conservation works programmes for WRC, the WPF has played a fundamental role in guiding the priorities and resource requirements for WRC-led funding applications to the Waikato River Authority ($7.8m), One Billion Trees ($3.2m), and the Hill Country Erosion Fund ($4.3m).

2.9 Validation and assessment of value

2.9.1 Validation and peer review

The WPF is a WRC ("in-house") developed framework, developed, and incrementally revised to meet the requirements of various WRC soil conservation projects and work programmes. As such, it's robustness is often questioned. With this in mind, an external peer review of the WPF was undertaken as part of Phase 1 development of the WPF (Hill and Borman, 2016). The external peer review was carried out in February 2015. The review panel included staff from NIWA, DairyNZ, and the Department of Conservation. As a result of the peer review, recommendations were made by the panel and incorporated into the Phase 2 development of the WPF (Hill and Borman 2016). In 2020, a review of the WRPP was undertaken to assess the use and future development of the WPF. The review process involved WRC Science and ICM staff. The findings of the review are provided in a report by Hill (2021).

2.9.2 Assessment of value

An assessment of the value of the WPF can be made against other more commonly used national approaches used for catchment management of contaminants. Based on comparisons outlined in Hill (2021), the WRPP had the following disadvantages and advantages.

Disadvantages included:

- is not an independently developed framework provided by an external science research provider,
- it is not a nationally used framework, or recognised approach, although it does make use of nationally accepted models, such as SedNetNZ, CLUES, and other nationally available data such as the LCDB,
- lacks the research development and scientific rigour (and funding) provided for the development of the other approaches, and
- requires specialist GIS and Science input for its development and operation.

Advantages included:

- it has been developed "in-house" which provides the flexibility to undertake revisions as required and customise the framework and its outputs to meet Council needs in a timely manner,
- using the framework directly involves WRC staff, including those that implement work on the ground, and so there is better ongoing support and a greater element of connectivity and realism that is not likely to be achieved with other externally provided approaches,
- it uses existing datasets, including those developed by WRC, and applies them to help manage issues relevant to WRC,

- it utilises multiple model outputs to provide single, more interpretable factor outputs that are easier to communicate and reduce the barrier for information uptake in the organisation, and
- in comparison to a research organisation-developed product, it is low cost, updatable, and directly relevant to WRC needs.

Aside from limitations governed by data availability, the WPF includes many necessary generalisations and assumptions throughout. These generalisations and assumptions are required to allow the combination of all the different data used and simplify the complexity of the spatial analyses. This does compromise the “scientific robustness” of the approach but does allow for (relatively quick) delivery of meaningful outputs for WRC use.

The WPF is not intended to prescribe the priorities or exactly which mitigations should be used or the exact placement of mitigations. Instead, its value is in providing a synthesis of multiple catchment data and a consistent, meaningful, and approachable picture of the relative soil conservation related priorities within an area of interest. It is a tool to help support management decisions.

3 WPF for soil conservation

3.1 Background

This report presents how the WPF can be used in catchments for guiding soil conservation priorities by land management staff. There are a number of background considerations that led to the current approach:

1. WRC were interested in a simple prioritisation model that could be completed in a short period (6 months),
2. requirement for a flexible framework to add new data to as it becomes available (e.g. updated land cover and land use change),
3. a desire to use all the data WRC has rather than individual competing models,
4. the requirement for objective outputs to support priorities within and across management zones in the Waikato region,
5. the ability to link local issues to upstream issues,
6. visual spatial outputs as well as data for assessment of issues, and
7. tools and techniques for progressively breaking down areas into more manageable units and optimally planning mitigations.

3.2 Purpose

The purpose of the Waikato Prioritisation Framework for soil conservation is to provide a consistent approach for the planning and implementation of the mitigations for soil conservation across the Waikato region.

The Waikato Prioritisation Framework also informs Waikato Regional Council's Strategic Directions and the objectives, policies, and methods of the WRC's key statutory documents including the Waikato Regional Policy Statement (RPS) and the Waikato Regional Plan (WRP).This report covers the WPF, its use for soil conservation including its ability to impose general soil conservation mitigations used by WRC to estimate the cost of the mitigations and estimate the impact of the mitigations on reducing sediment and other water quality related contaminants. Collectively, the outputs provided, assist with decision making around soil conservation work programmes for WRC and others.

4 Methods

The Waikato Prioritisation Framework for soil conservation incorporates a series of components and geospatial processes that are collectively used to simplify model data from multiple source, thereby increasing data accessibility to a broader and more diverse audience, while remaining science based. The methods employed are flexible enough to allow adjustments to be made spatially (for example by management zone) or temporally (as improved input data becomes available) while retaining a consistent geospatial approach. A summary of the Waikato Prioritisation Framework components are shown in Table 2.

Table 2. A summary of the current Waikato Prioritisation Framework for soil conservation components.

Component	Description
Framework base	Spatial analysis base consisting of reach-watersheds derived from REC2, combined with a regional land use layer overlay.
Datasets and metrics	Available regional and national spatial model datasets.
Factors (risks)	Soil conservation and water quality factors (risks) considered important by WRC and linked to soil conservation mitigations that WRC implement.
Key issues	Individual factors are combined to address the key issues of soil conservation and related water quality risks.
Scoring and ranking	Relative risk scores are generated for all factors. For key issues, combine individual factors are combined and weighted relative (risk) scores are estimated for each key issue. Relative risk scores are used to rank and prioritise areas.
Mitigations	Soil conservation related mitigations are identified.
Costs	Costs for implementing soil conservation mitigations are estimated.
Reductions	Reductions in water contaminants resulting from soil conservation mitigations are estimated for sediment, nitrogen, phosphorus, and microbes.
Decision support outputs	Graphed relative scores and maps for a selected area which can range in size from region to sub-catchment.

The following WPF methods sections describe the components in Table 1 in greater detail. Mitigations, Costs and Reductions are described specifically for the soil conservation key issue sub-model in Section 6.

4.1 Framework base

Underpinning all geospatial analyses within the WPF are two geospatial layers; a hydrological network, and a land use layer. These provide the ‘base’ for the geospatial analyses.

4.1.1 Hydrological framework

The hydrological framework uses the River Environment Classification, v2.5 (REC2), (NIWA, 2019). The main advantages of using the REC2 is that it provides hydrological connectivity within and between catchments. Also, models such as CLUES use the REC river segments to perform calculations, it can be spatially aggregated to interrogate data at various scales, and it provides full regional coverage.

The River Environment Classification (REC2) consists of hydrologically contiguous surface waterway reaches and associated watersheds (upstream catchments). For the Waikato region there are about 60,000 reaches with associated watersheds (termed reach-watersheds), with an average area of about 50 hectares each (Figure 1).

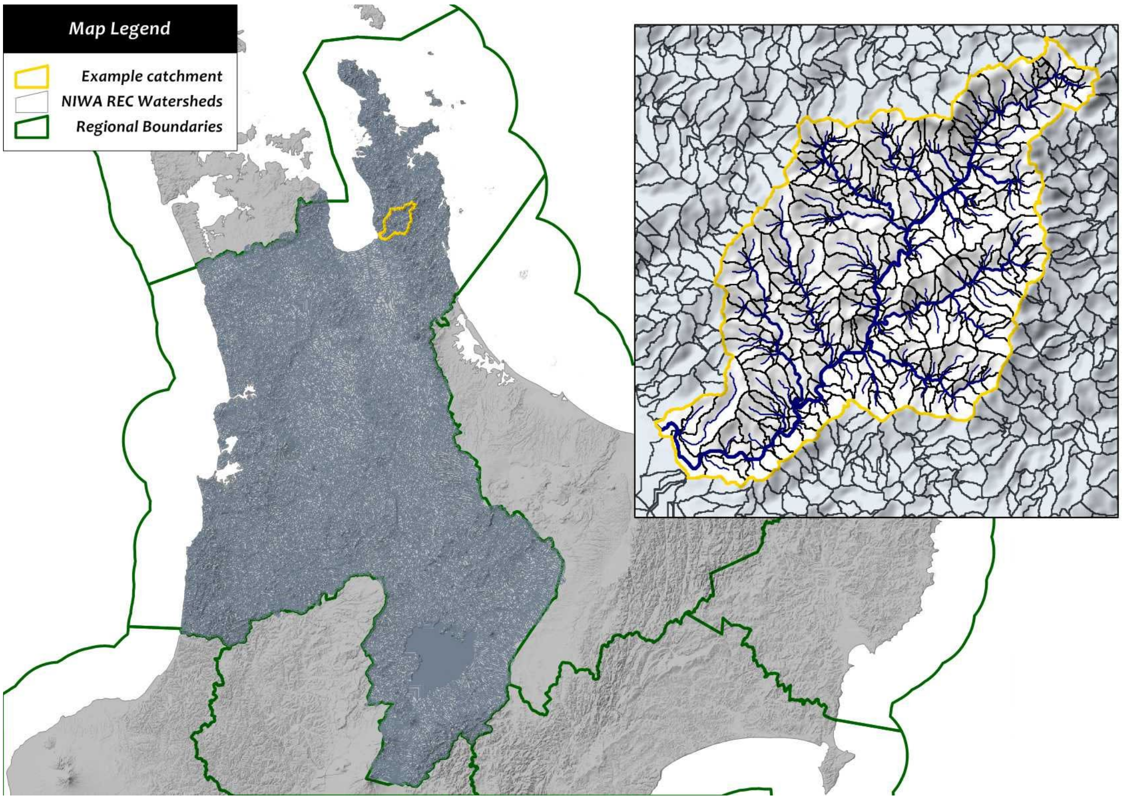

Figure 1. NIWA River Environment Classification reach-watersheds for the Waikato region (NIWA, 2021).

For the WPF, the REC2 has been extended to include additional attributes and geometrics allowing direct interrogation using spatial Structural Query Language (SQL). These extensions facilitate a variety of hydrology-based querying, including semi-instantaneous creation of derivative datasets including upstream tracing and attribute aggregation, hydrological indexing, catchment thresholding, and watercourse/catchment optimisation across a range of factors. It also allows for pre-calculated lookup tables to be related to the base framework and to be included in all SQL and spatial analysis.

The reach-watersheds comprising the hydrological framework, provide the finest scale spatial base for all analyses in the WPF. Data outputs for all reach-watersheds can be aggregated or grouped at multiple broader scales (e.g. aggregated to defined sub-catchments or management zones). This provides the flexibility to apply any spatially defined boundary to the data for analysis. Spatial datasets (such as the Landcover Database – LCDB) can also be overlain and interrogated to provide spatial outputs.

4.1.2 Land use layer

The land use layer is derived from land cover and land use spatial data. It is used to identify different types of land and underpins the estimates of contaminant generation, the placement of appropriate mitigations, and reductions expected from imposing mitigations.

Many of the models contributing to the input data in the WPF use their own land use layers for their model outputs. However, these layers are often outdated and do not reflect more recent land use change (e.g. the CLUES land use layer for the Waikato region was compiled using LCDB version3.0 (2008/09) land cover, and Agribase land use data of a similar date).

The land use layer in the WPF has been rebuilt to include more current land cover and land use data (land cover, LCDB v5.0, 2018 and land use, 2018 Agribase). Additionally, the decision making process for spatially allocating land uses and stock units within farms and the intensity of stock units has been refined, resulting in improved method transparency and repeatability. The detailed decision criteria for the revised land use layer are available as scripts and associated metadata held by the GIS Team at WRC.

4.2 Datasets and metrics

An objective of the Waikato Prioritisation Project was to make use of a number of externally developed models that provided data for estimating erosion, sediment, and potential contaminants such as nitrogen, phosphorous, and microbes (*E.coli*). These models were, in general, developed independently and constructed in different ways. The result was that they were good estimators of some components and not others (i.e. as with all models they had strengths and weaknesses). This provided the end user in WRC with a confusing and large amount of data to interpret when deciding on soil conservation priorities and mitigations. The WPF approach is to combine all available model data for a factor to utilise each model's strengths and simplify the combined data for easier interpretation for use. Additionally, as models are revised or new models become available, they can be incorporated into the WPF for use.

For each dataset, simple metrics have been selected to inform the factors identified. Metrics are generally area, length, or yield-based. The datasets and metrics used in the WPF are shown in Table 4. Additional details of the individual datasets/models used can be sourced from the original reports referenced in Table 3.

Table 3. Specific datasets used in the WPF.

	Dataset/model	Metric	References
Framework layers			
Hydrological	River Environment Classification v2.5 (REC2)	REC2 derived reach-watersheds.	https://niwa.co.nz/freshwater-and-estuaries/management-tools/river-environment-classification-0
Land use/landcover	LCDB v5.0 and flattened 2018 AgriBase™ farm type	Updated land use layer used to derive stock unit density, landcover, and integrated into CLUES for modelling generated yields.	https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/ AgriBase™ 2018 data for the Waikato region
Factors			
Sediment	Updated sediment load estimator for New Zealand	Generated sediment yield estimate for reach-watersheds.	Hicks et al. (2019)
	CLUES (WANSY revised) sediment generated	Generated sediment yield estimate for reach-watersheds.	Haddadchi and Hicks (2016)
	NZEEM® sediment generated	Generated sediment yield estimate for reach-watersheds.	Palmer et al. (2013)
	SedNetNZ sediment generated	Generated sediment yield estimate for reach-watersheds.	Dymond et al. (2016)

Hillslope erosion	NZLRI erosion type, slight to severe severity	Identifies areas of hillslope erosion; areas of NZLRI hillslope erosion types with slight to severe severity.	https://lris.scinfo.org.nz/layer/48054-nzlri-erosion-type-and-severity/ Newsome et al. (2008)
	Highly Erodible Land (HEL) landslides and earth-flow	Identifies areas of hillslope erosion; HEL identified areas of landslides and earth-flow.	Palmer et al. (2013)
Stream-bank erosion	NZLRI erosion type and severity	Identifies areas of streambank erosion; areas of NZLRI streambank erosion with slight to severe severity.	https://lris.scinfo.org.nz/layer/48054-nzlri-erosion-type-and-severity/ Newsome et al. (2008)
	SedNetNZ streambank erosion sediment generation	Identifies areas of streambank erosion based on generated sediment yield.	Dymond et al. (2016)
Vegetation Protection (land cover related land use pressure)	LCDB v5.0 land cover and NZLRI Land Use capability classification criteria	Identifies where land cover is considered less than the land's capability; LUC 7 and 8 in pasture.	https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/ Lynn et al. (2009)
Stock intensification (stock-related land use pressure)	AgriBase™ stock unit density	Identifies where stock unit density is considered greater than the land's capability; Stock unit density 17 to >35 SU on LUC classes > LUC 4.	AgriBase™ 2018 data for the Waikato region Lynn et al. (2009)
WRC works	WRC compartments	Identifies areas of soil conservation work (retirement and planting).	WRC Conquest unpublished data
	WRC fencing	Identifies areas of soil conservation work (fencing).	WRC Conquest unpublished data
Nutrients	CLUES Total N generated yield	Generated N yield estimate for reach-watersheds.	Parshotam et al. (2012); Elliott, A.H. et. al. (2016)
	CLUES Total P generated yield	Generated P yield estimate for reach-watersheds.	
Faecal microbes	CLUES E. coli generated yield	Generated E. coli (count) estimate for reach-watersheds.	

Data for the analyses was used as produced from the datasets, except for CLUES data for nutrients and *E. coli*. Following consultation with NIWA staff (the CLUES model developers and custodians) the model was run for N, P and *E. coli* excluding point source inputs. This was undertaken to focus the outputs on non-point source generation; point source model inputs were found to confound catchment scores because of the way they are included in the CLUES model. The latest land use data was used for the CLUES model rather than its standard land use layer.

4.3 Factors

Factors can be considered soil conservation related risks, for example, erosion of hillslopes, runoff of nutrients from the land, lack of riparian fencing allowing stock to access streambanks and reduced streambank stability. For each factor, a metric is used to calculate a factor score, which are used to calculate scores for key issues. Individual factors are represented by a metric, which is an attribute provided by one or more of the spatial models providing the input data for the framework. The factors currently defined in the WPF are shown in Table 4.

Table 4. The factors currently defined in the WPF.

Factor	Rationale
Soil conservation key issue factors	
Sediment	Reducing sediment to waterways is a key focus for WRC in relation to surface water quality. A range of land management and natural causes contribute to sediment, but all relate to soil conservation actions.
Hillslope erosion	Hillslope erosion is a main focus of WRC soil conservation work programmes.
Streambank erosion	Stream-bank erosion is a major component of the overall erosion in the Waikato region given the large area of lowlands and incised waterways.
Vegetation protection	Identifies where land use does not match land use capability, and pasture where soil conservation actions are likely to be required. WRC soil conservation works focus on NZLRI LUC class 6e, 7 and 8 land.
Stock pressure	Intensification on less capable land (NZLRI LUC 6e, 7 and 8 pasture) requires appropriate land management to avoid increased sediment generation and erosion. High stocked farms are considered 17.5 to >35 SU (mid intensity dairy land use and greater).
WRC works	Includes existing soil conservation schemes where there has been past soil conservation requirement; future maintenance is likely, and resources have been invested.
Water quality key issue factors	
Total N - land cover/use generated	A major focus of the surface water quality issue in the region. N loss to waterways is predominantly through leaching. Reducing N inputs to the land reduce the potential for N loss to waterways. Identifying and targeting areas with high N generation can reduce a greater portion of E.coli entering waterways.
Total P – land cover/use generated	A major focus of the surface water quality issue in the region. P loss to waterways is predominantly through soil loss and sediment entering waterways. Reducing P inputs to the land and reducing erosion reduce the potential for P loss to waterways. Identifying and targeting areas with high P generation can reduce a greater portion of E.coli entering waterways.
E. coli – land cover/use generated	A major focus of the surface water quality issue in the region. *E. coli* loss to waterways is predominantly through surface runoff. Identifying and targeting areas with high *E. coli* generation can reduce a greater portion of *E.coli* entering waterways.

4.3.1 Calculating factor scores

4.3.1.1 Reach-watershed factor score

The geospatial analyses to calculate scores uses MANIFOLD® GIS software and SQL language to write scripts to automate and speed up the analysis. This allows the analysis to be updated regularly if changes are required, or input datasets are modified or added. The analysis requires a score to be computed for each reach-watershed. The final scores are normalised to enable the combination and comparison of factors across the catchment.

Additionally, data are normalised where multiple datasets are used to derive a factor score (e.g. CLUES sediment and SednetNZ can both be used to derive the sediment factor score). This approach allows data of different scales to be aggregated to derive a single threat score. The final score for a reach-watershed (the reach-watershed factor score) has two components: a *reach score* and an *upstream score*.

The *reach score* is derived using the proportion of the factor that occupies the reach-watershed. It represents the factor's upstream contribution from the reach-watershed. For example, we can estimate the length of streambank with direct stock access by using data from the Waikato Regional Riparian Characteristics Survey which provides quantitative estimates on fencing extent and efficacy (Norris et al., 2020). The length contribution of each unfenced section is summed, and the total proportion of unfenced bank length is calculated against the total length of bank within the reach. Higher scores are given to reach-watersheds with a higher proportion of unfenced bank length. Similarly, for area-based factors, higher scores are given to reach-watersheds with a higher proportion of area with the factor. For generation-based factors (such as sediment generation) scores are given to reach-watersheds based on absolute generation values.

The *upstream score* component is included to reflect the impact/contribution of the upstream catchment above a reach-watershed. This has the added effect of "averaging the scores in closer proximity (in a hydrological context) to simplify the visual pattern later in the prioritisation outputs.

The *upstream score* is derived by averaging all upstream reach-watershed scores for every reach-watershed. The final reach-watershed score is derived by summing the *reach score* and *upstream score* for each reach and scaling the result to yield a normalised score scaled from 0-100:

Reach-watershed factor score =

((Reach score + Upstream score) / Max (Reach score + Upstream score)) * 100

4.3.1.2 Calculating scores for different scales

The following general steps explain how the factor scores at the different scales are derived:

1. Calculate named catchment scores by summing all reach-watershed scores for the named catchment and dividing the total by the named catchment area,
2. Normalise named catchment scores as follows:

   For regional outputs (by named catchment):

   Normalise (1-10) all named catchment scores for each individual factor using regional maximum and minimum scores for individual factors,

   For management zone outputs (by named catchment):

   Normalise (1-10) all named catchment scores in a management zone for each individual factor using management zone maximum and minimum scores for individual factors, and
3. Apply weightings to factors and sum weighted factor scores for each key issue to get the final key issue scores for the named catchments, either regionally or for management zones.

4.3.2 Ranking scores

The ranking of scores for individual factors and combined factors (key issues), mitigation costs, and reductions requires that the data be normalised across attributes to provide relativity in the scoring and ranking analysis. This has the following advantages:

- allows the bringing together of multiple datasets,
- provides flexibility to incorporate new data as it becomes available,
- it is hydrologically connected,
- consideration of the upstream catchment condition and inclusion in the score for a reach-watershed, and
- it is scalable to provide information and a framework for whole of catchment and sub-catchment scale assessment.

For individual factors and mitigations, the ranking is simply based on the normalised score for the reach-watershed. For key issues, the ranking is based on the weighted score sum of all contributing factors.

For factors, the highest rank is assigned to the factor with the highest score. For mitigations, the highest rank is assigned to the lowest cost and the highest reduction. The named catchments are ranked by summing all the factor scores for an issue. For the regional ranking, all catchments are ranked irrespective of the management zone in which they reside. For the management zone, ranking only catchments within the selected management zone are considered.

5 Decision support outputs

5.1 Introduction

The WPF database can be interrogated to produce outputs at various scales as required; for whole of catchment, sub-catchment, and individual reach-watersheds. The WPF output formats include graphs, tables, and static maps. The outputs were developed in consultation with WRC staff to provide simple to understand information for a broad audience. This is an important consideration for ensuring science is accessible for all those involved in WRC catchment work programmes.

One of the main features of the map outputs is that they make use of visual representation of the data. The colour ramps used are adjusted to the scale of the area of interest by recalculating the data to present as relative normalised scores for only the area of interest. This can be the whole region, management zone, sub-catchment, or reach-watersheds. This provides a visual relative normalised representation of the data which allows for easier visual interpretation. Additionally, graphed data are treated the same and correlate with the map data. The area of interest can show either the normalised score derived from a regional analysis, or one derived from the area of interest only. In this way it is possible to show rankings for an area of interest based on either their regional or local importance. The map output adjusts the colour ramp to correlate with the normalised scores for the area of interest.

The WPF provides a suite of outputs for guiding catchment priority decision making. These outputs are described in Table 5.

Table 5. Outputs for determining catchment priorities and implementing mitigations.

Outputs	Application
Individual factor score maps	Provide a simple prioritisation solely on where the greatest relative factor scores have been estimated. This approach does not consider the effects of mitigation placement and the associated costs and reductions.
Soil conservation key issue maps and graphs	Provide a simple prioritisation guide based on where the greatest relative normalised scores for the factors contributing to the soil conservation key issue have been estimated across a specified area of interest. This approach does not consider the mitigation placement and the associated costs and reductions.
Area and per cent tables	Shows the area and per cent cover of risk classes in the area of interest.
Soil conservation mitigation cost tables	Provide a prioritisation guide based on the where the greatest relative soil conservation mitigation costs have been estimated across a specified area of interest. This approach is most useful when used in conjunction with the information provided in the mitigation reduction tables and consideration of the factor and key issue maps and graph data.
Soil conservation mitigation reduction tables	Provides a prioritisation based on where the greatest relative reductions have been estimated across a specified area of interest. This approach is most useful when used in conjunction with the information provided in the mitigation cost tables and consideration of the factor and key issue maps and graph data.

Collectively, the five outputs are steps towards a process that combines all the information to provide a cost-benefit type prioritisation decision making process. The process firstly considers individual factors, combines the factors to focus on soil conservation then applies mitigations, including their spatial placement and costs, and finally estimates the likely water quality improvements associated with the collective mitigations placed. Individually, each output will suit different land management decision making objectives. Examples of the outputs are provided in the worked example for the West Coast management zone, presented later in this report (Section 7).

Numerous other subsets and combinations of the output data are possible and can be collated as required for prioritisation assessments on a case by case basis.

5.2 Individual factor score maps

Individual factor score maps provide a visual representation of an individual factor for an area of interest. These maps are useful for visually assessing the range of factor scores for the area and identifying areas for investigation for the individual factor. Figure 2 provides an example factor score map (sediment) for the Upper Waikato management zone. The higher the score the greater the risk and the redder the colour.

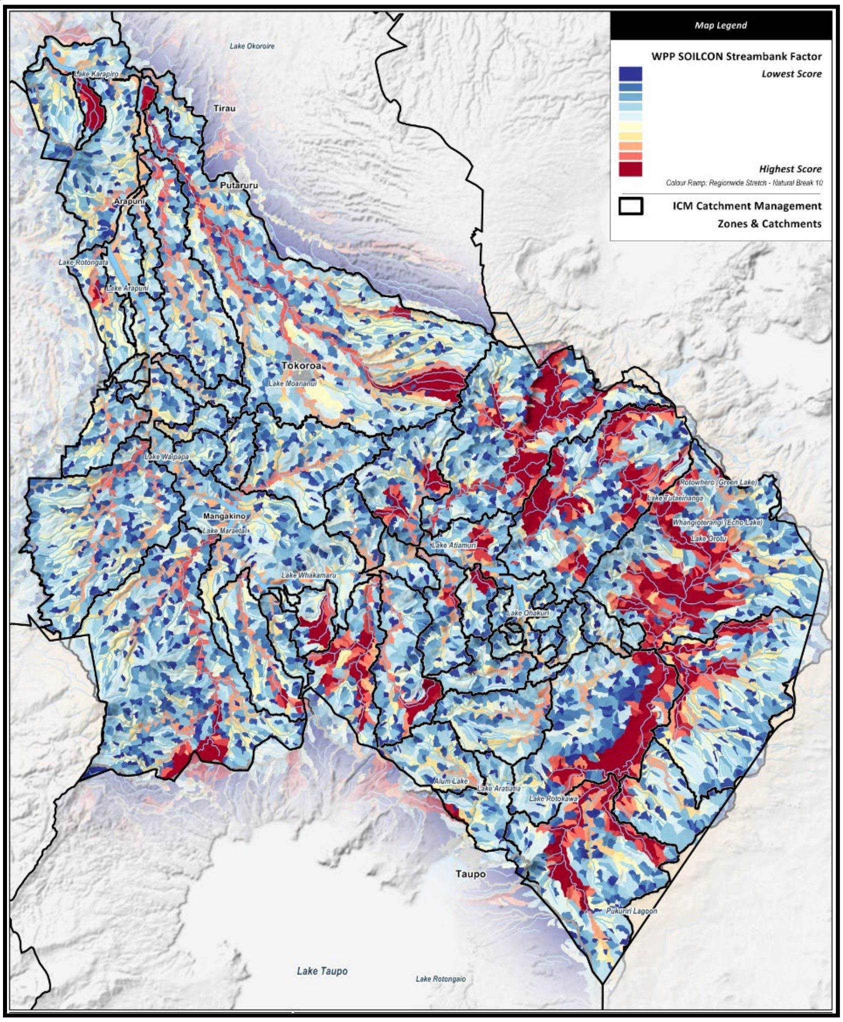

Figure 2. Streambank erosion factor score map for the Upper Waikato management zone. The higher the score the greater the risk and the redder the colour.

5.3 Key issue outputs

Key issue outputs include maps and associated graphs depicting the combined scores of the factors contributing to the key issue. As with the individual factor score maps, the key issue maps are useful for visually assessing the range of scores for the area and identifying areas for investigation. Figure 3 provides an example key issue factor score map (soil conservation) together with an example graph of the contributing individual factor scores for selected sub-catchments in the Upper Waikato management zone.

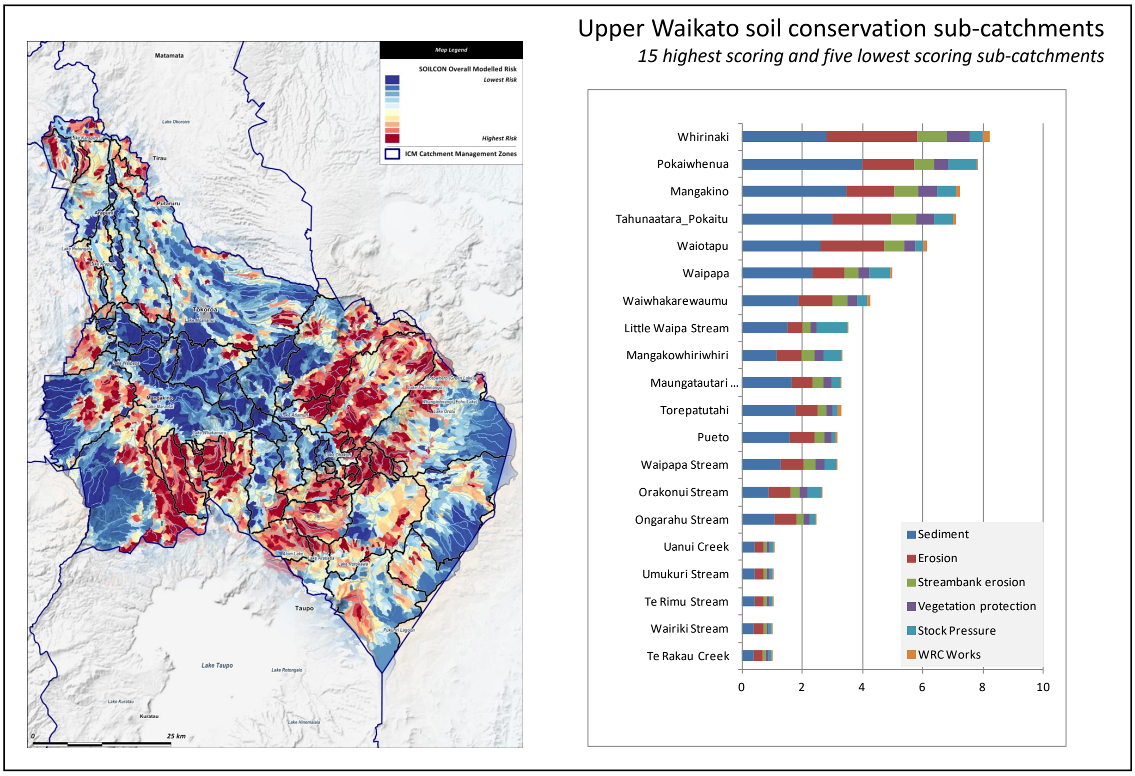

Figure 3. Soil conservation factor score map and graph example for the Upper Waikato management zone.

The associated key issue graphs show the relative contribution each factor makes to the key issue for a given sub-catchment. Sub-catchments can be ranked according to their key issue score (the combination of all contributing factor scores) to assist with prioritisation.

Additionally, the breakdown of the relative contribution each factor makes to the key issue for a given sub-catchment can be used to target individual factors with high scores even though the sub-catchment may have a low overall issue score and ranking.

5.4 Outputs at different spatial scales

A key feature of the WPF is its ability to normalise reach-watersheds scores according to different spatial scales and provide outputs to show relative scores regionally, for management zones, or for sub-catchments within management zones (Figure 4). For example, high relative scores for erosion can be targeted within a sub-catchment that lies within a management zone with regionally low relative erosion scores.

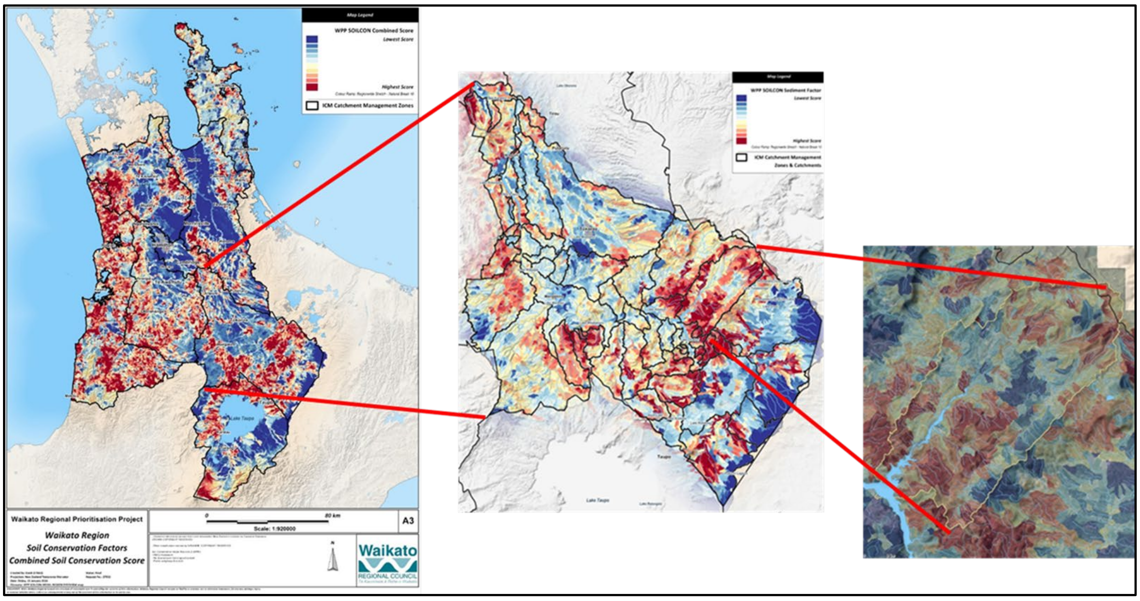

Figure 4. Maps of soil conservation scores normalised at different scales; regionally, within a management zone, and for a sub-catchment within a management zone.

5.5 Mitigation cost and reduction data tables

Mitigation cost tables provide summaries of the costs associated with implementing the soil conservation mitigations for sub-catchments and management zones. These can be presented for individual mitigations, grouped into riparian or hillslope mitigations, or further combined to provide the total cost for implementing all mitigations. Similarly for mitigation reductions, tables can be combined in various ways to present the percentage water contaminant reductions resulting from implementing the mitigations.

Additionally, combining costs and reductions provides useful data for assessing where the greatest reductions can be made for the least cost. Figure 5 provides mapped examples of ranked costs and reductions for the Upper Waikato management zone.

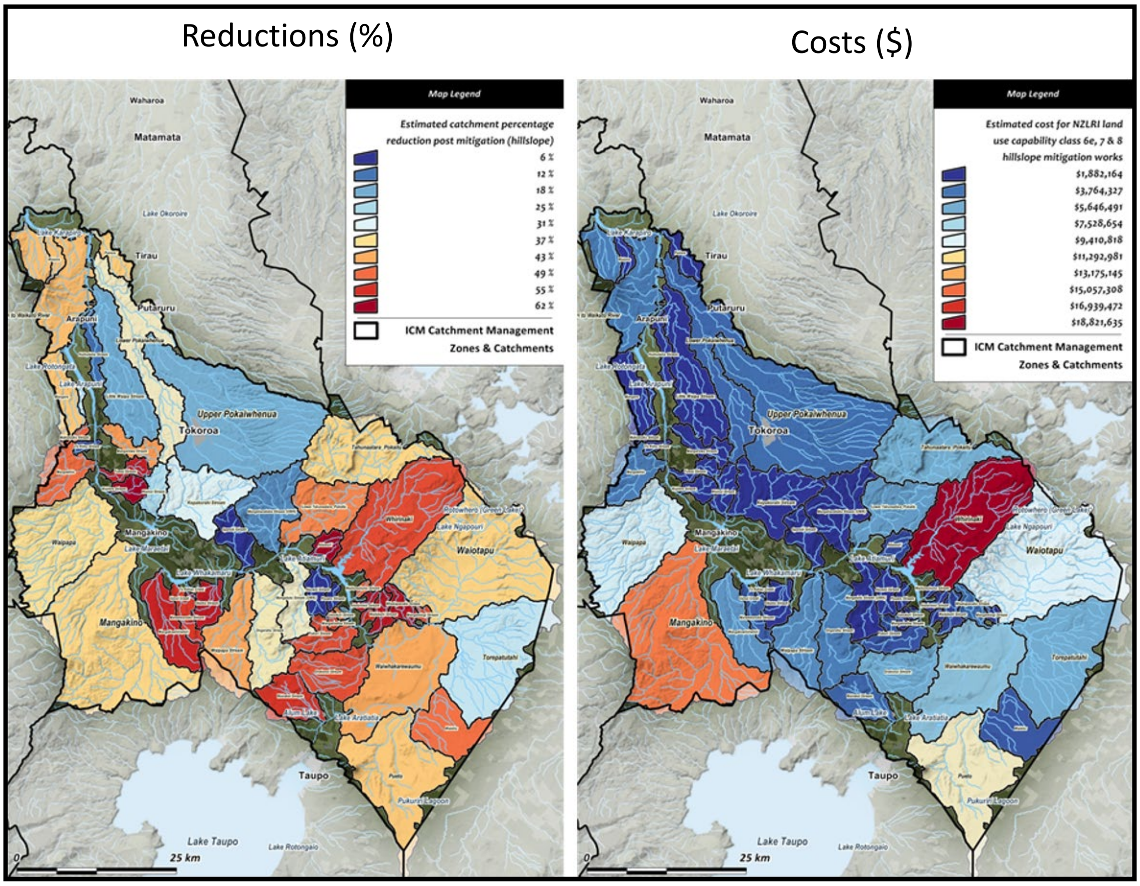

Figure 5. Mapped examples of ranked reductions and costs for the Upper Waikato management zone.

6 Application of the soil conservation sub-model

6.1 Soil conservation key issue factors

For the soil conservation key issue, the WRC ICM goals place a high importance on sediment and erosion (80% of the score combined). Land use pressures, represented by vegetation protection and stock pressure are weighted next highest (17.5% of the score), and WRC works are weighted the lowest to have the least influence on the score (2.5% of the score). The factors and their weightings contributing to the soil conservation key issues in the WPF are shown in Table 6.

Table 6. The factors and weightings used to calculate the soil conservation key issue score.

Factor	Rationale	Weighting
Sediment	Reducing sediment to catchment waterways is a focus for WRC soil conservation programmes.	0.4
Hillslope erosion	Hillslope erosion is the likely main contributor to sediment in catchments and a focus for WRC soil conservation programmes. Stabilising erosion on pasture retains the soil in-situ and maintains the productive capacity of the land.	0.3
Streambank erosion	Streambank erosion is a large contributor to sediment in catchments and a focus for WRC soil conservation programmes. Stabilising erosion along waterways reduces sediment directly entering waterways.	0.1
Vegetation protection	Ensuring the landcover is matched to the capability of the land reduces erosion and sediment generation.	0.1
Stock pressure	Ensuring the stock unit intensity is matched to the capability of the land reduces erosion and sediment generation.	0.075
WRC works	Where there has been past soil conservation requirement; future maintenance is likely, and resources have been invested. Past work indicates community willingness for soil conservation.	0.025

6.2 Mitigations, costs, and reductions

6.2.1 Introduction

The inclusion of soil conservation mitigations aims to identify actions that can be used by land managers to address soil conservation and water quality issues for a given area. The inclusion of the mitigations provides a way of estimating the “catchment scale” efficacy, in terms of reducing threats, and the cost of doing so.

A key step is defining the spatial extent of each mitigation and developing criteria for imposing the mitigations onto the hydrological framework. This process uses a range of nationally and locally available datasets and current literature on the effectiveness of mitigations and estimates of costs.

The WPF logically assumes that all mitigations cannot be placed everywhere in the catchment. Mitigation criteria have been developed in a way to place mitigations where they are most likely to be used. Criteria are based on expert knowledge of currently known soil and land management practices. A similar approach has been used to prioritise soil conservation across catchments for the Waikato and Waipā River Restoration Strategy (Nielsen et al., 2018).

The GIS processes are structured so that new data can be readily incorporated and the components re-run to update the output database and maps. The following section of the report provides the criteria used to define mitigations, assumptions and limitations, and opportunities for improvement.

6.2.2 Mitigation criteria

A set of criteria are used to define and describe the mitigations used in the WPF (Table 7).

Table 7. Criteria used to define individual mitigations.

Mitigation criteria	Details
Description	Describes the type of mitigation and its general placement, benefits, and likely relative costs compared with other mitigations.
Spatial placement (GIS criteria)	Criteria for placing the mitigations in the catchment, including factors like along reaches, an area of a land use, and land use capability; either a length, an area, or a density per area.
Costs	An estimate of the cost of implementing a mitigation, either a cost per length, or cost per area or per treatment. An estimate of farmer time is included. Costs have been grouped into high, medium, and low classes as per the "*Menu of practices to improve water quality*".
Reductions	Reduction estimates are based on available literature and are represented as a percentage reduction.
Assumptions	Assumptions that were made in defining the mitigation criteria and spatial placement.

6.2.3 Mitigation suite

Six soil conservation mitigations have been developed for the WPF (Table 8). However, for each management zone these may be revised based on specific soil conservation practices in each management zone. The riparian management mitigations are based on the level of riparian protection provided by fencing (to exclude stock), and woody vegetation (to increase soil stability provided by tree roots). The hillslope management mitigations are based on land limitations as indicated by the LUC sub-class, the presence of active erosion, and where the limitations of the land indicate that the current land use (landcover) is not capable of being sustainable in the long term. All six mitigations are those implemented by WRC in their catchment works programmes.

Table 8. The suite of soil conservation mitigations used in the WPF.

Mitigation	Description
Riparian management	
Riparian fencing	Fencing provides stock exclusion. Removes direct input of contaminants to waterways. Rank grass acts as a buffer for sediment, nutrients, microbes as well as stabilising banks.
Riparian woody vegetation	Woody vegetation acts as a buffer for sediment, nutrients, microbes as well as deep roots stabilising banks and removing some nutrients.
Hillslope management	
Hillslope pasture stability -LUC class 6e land	Unstable land in broken pasture with 26 to 35 degree slopes, identified using LUC 6e polygons and 20m DEM refined slope class if there is sufficient data (e.g. LIDAR).
Hillslope plantations -LUC class 7 land	Land >35 degrees identified using LUC 7e polygons and 20 m DEM refined slope class.
Hillslope retirement -LUC class 8 land	Steep areas not capable of supporting pasture or plantation forestry according to LUC classification), i.e. conservation land only.

Hillslope active erosion	Active bare soil erosion areas (e.g. slips) on hillslopes. Stabilisation of these areas reduces sediment generation.

6.2.4 Spatial placement of mitigations

Not all mitigations should be placed everywhere in the catchment. Mitigation placement is limited to the areas which are realistic for placement and targets threats. Estimating where mitigations can be placed and the relative areas where they are effective will assist with prioritising actions in the catchment as well as estimates of reductions and costs.

The specific placement of mitigations to target threats within a catchment, can be identified at a broad scale. For example, when identifying specific areas for mitigating potential soil erosion on pasture or poplar pole planting on pasture, only a portion of the pasture area identified will require pole planting, which cannot be delineated at a catchment scale. The refined placement of most mitigations will require a combination of aerial photo interpretation (a desktop exercise) or farm scale field assessment (e.g. a farm plan or LUC assessment).

6.2.5 Calculating mitigation costs

Mitigation cost estimates are based on those used for the Waikato and Waipā River Restoration Strategy (Neilson et al., 2018a and 2018b) but are reviewed for each management zone as required. The review process involves workshops with WRC staff, land managers, and can include community representatives.

Mitigations are either area based (e.g. planting) or length based (e.g. fencing). Expert knowledge is used to determine the cost of a mitigation in a management zone. Simple metrics are determined, such as $25/m for fencing. These mitigations can then be imposed onto the framework in specified locations where they are required, and cost estimates derived for reach-watersheds. In turn, mitigation costs associated with individual reach-watersheds can be aggregated to provide mitigation cost estimates for an area of interest.

For each LUC sub-class a mix of mitigations may be used, and not all land may require treating. Mitigations implemented vary throughout the region's management zones, largely because of differences in geology, soils, rainfall, topography, and land use management. For this reason, the mitigations developed, are specific to each management zone. An example of mitigation costs and criteria for the West Coast zone is provided in Table 13 (Section 7.4).

6.2.6 Estimating mitigation reductions

The WPF has developed water contaminant reduction estimates for all soil conservation mitigations. Reduction estimates for sediment, nitrogen, phosphorus, and faecal microbes are included. Mitigation reduction estimates are based on available literature. The main sources of literature used to determine the mitigation reductions included:

- McDowell et al. (2013),
- Hill and Blair (2005),
- The menu of practices to improve water quality (Dairy farms and Drystock farms), and
- Industry-agreed Good Management Practices relating to water quality (Version 2).

However, published estimates of reductions for nitrogen, phosphorous, sediment and faecal microbes are variable depending on land use management, landscape, and mitigation implementation. For example, McDowell et al. (2013), provides very high, high, medium, and low effectiveness ratings, and the *Menus – Practices to improve water quality* provide percentage ranges with their ratings, which differ depending on the contaminant and land use.

Sediment estimates for hillslope and riparian management, are based on Hill and Blair (2005) who reviewed Soil Conservation Research and Catchment Environmental Monitoring information in the Waikato Catchment. Sediment reduction estimates were confirmed and used for the Waikato Regional Prioritisation Project (Hill and Borman, 2016) and the Waikato and Waipā River Restoration Strategy (Neilson et al., 2018a and 2018b). Its use in the WPF provides some continuity with existing guidance provided by council for funding soil conservation.

Where possible the WPF has also approximated nitrogen, phosphorus, and faecal microbe mitigation reductions to align with the Low, Medium, and High ranges of the *Menus – Practices to improve water quality (*Menus*)*. This is in part to provide some continuity with existing guidance available to landowners. Generally, a midpoint value within the range has been used but, in some situations, a lower or higher value in the range has been applied.

The literature source of the individual reduction criteria (for N, P, sediment, and faecal microbes) applied for each mitigation are summarised in Table 9.

Table 9. The literature source of the individual reduction criteria (for N, P, sediment, and faecal microbes) applied for each mitigation.

Mitigation	**Basis (source information) for efficacy**			
	Nitrogen	**Phosphorus**	**Sediment**	**Microbes**
Riparian management	Same reductions likely for either fenced and ungrazed grass margins or planted and fenced margins.			
Riparian fencing	Menus	Menus	A 60% reduction used in WRPP, based on Whatawhata research data summary in Hill and Blair (2005).	Reduced from High in the Menu to Medium based on Collins & Rutherford (2004).
Riparian woody vegetation				
Hillslope management				
Hillslope pasture stability (LUC 6e land)	Menus	Menus	A 60% reduction used in WRPP, based on Whatawhata research data summary in Hill and Blair (2005).	Menus
Hillslope plantations (LUC 7 land)	Assumes unstocked and nitrogen decrease similar to pine and indigenous vegetation.	A 60 % reduction used in WRPP, based on Whatawhata research data summary in Hill and Blair (2005).		Assumes unstocked and microbes decrease to be like pine and indigenous land cover.
Hillslope retirement (LUC 8 land)				
Hillslope active erosion	Assume same as Hillslope pasture stability.	Assume same as Hillslope pasture stability.		Assume same as Hillslope pasture stability.

6.2.7 Current WPF mitigation reductions

The current mitigation reduction percentages used in the WPF are presented in Table 10. These percentage reductions are best estimates based on the currently available research literature and remain constant for all WPF analyses. As new research literature becomes available, these percentage reduction can be revised. Also, as new mitigations are developed, they can be added to the WPF, and mitigation reductions can be assigned. Mitigation reductions can also be evaluated/updated via effectiveness monitoring programmes (e.g. WRC's Catchment Environmental Monitoring) which provide a valuable feedback loop to model evaluation/updates.

Table 10. The current mitigation reduction percentages for water contaminants used in the WPF.

Mitigation	Nitrogen	Phosphorus	Sediment	Microbes *(E. coli)*
Riparian management				
Riparian fencing	10%	30%	60%	20%
Riparian woody vegetation	10%	30%	60%	20%
Hillslope management				
Hillslope pasture stability -LUC class 6e land	0%	10%	60%	0%
Hillslope plantations -LUC class 7 land	70%	80%	60%	80%
Hillslope retirement -LUC class 8 land	10%	30%	60%	20%
Hillslope active erosion	10%	30%	60%	20%

6.2.8 Mitigation limitations and sensitivity

The WPF aims to include mitigations that are as realistic as possible. For this reason, mitigations are developed and agreed upon through workshops, with input from scientists, land managers, land management practitioners, and community representatives.

For all mitigation related estimates there is a high level of uncertainty around the mitigation reductions that can be achieved. This is primarily because the mitigation reduction estimates are highly variable depending on the local conditions, farm management practices, and implementation effectiveness.

In the WPF, the soil conservation mitigations focus on actions that are more general, such as fencing and planting. Site specific mitigations such as detainment bunds, bridges, and constructed wetlands are not included. This is because of the site specific requirements of these mitigations (for placement, construction, and cost).

The percentage reductions used for each mitigation could be challenged for the purpose of their application. However, the main consideration is that they are within an acceptable range that is likely to provide a relative picture of likely reductions that can be expected across an area of interest (e.g. a sub-catchment or management zone). The WPF is flexible and able to adjust these reduction estimates as new research becomes available.

Factors that are likely to affect the mitigation-related outputs are the spatial placement criteria, reduction percentages, and cost assumptions applied. For example, applying pole planting to 50% of LUC class 6e pasture requires an assessment of how much of the 6e pasture is likely to require pole planting, whether the LUC 6e mapped area is correctly identified, the spacing of the poles (for the cost calculation), and what reductions are likely to be achieved.

In general, developing mitigation criteria, placing mitigations, and using mitigations spatially requires many assumptions at different stages of the process. Throughout the process, a key consideration is to maintain the involvement of WRC staff and catchment landowners to keep the criteria as realistic as possible.

7 Worked example (West Coast)

7.1 Introduction

This worked example serves to show how the WPF is used for a specific management zone sub-catchment prioritisation assessment. In this case, the example is for the West Coast management zone. It should be noted the example provided is an illustrative example only and the data provided is only part of that used in the actual prioritisation assessment for the West Coast. The West Coast prioritisation assessment used both the soil conservation and water quality sub-models combined. This example only presents results from the soil conservation sub-model and the water contaminant reductions from soil conservation mitigations.

7.2 Factors and key issues

The factors and key issues used in the West Coast prioritisation assessment are shown in Table 11.

Table 11. The factors and weightings used to calculate the soil conservation and water quality issue scores.

Key issue	Factor	Weighting
Soil conservation	Sediment	0.4
	Hillslope erosion	0.3
	Streambank erosion	0.1
	Vegetation protection	0.1
	Stock pressure	0.075
	WRC works	0.025

7.3 Datasets and metrics

The datasets and metrics used in the West Coast assessment are as shown in Table 12.

Table 12. Specific datasets used for the West Coast prioritisation assessment.

Attribute	Dataset/model	Metric
Framework layers		
Hydrological	River Environment Classification v2.5 (REC2)	REC2 derived reach-watersheds.
Land use/landcover	LCDB v5.0 and flattened 2018 AgriBase™ farm type	Updated land use layer used to derive stock unit density, landcover, and integrated into CLUES for modelling generated yields.
Area boundaries		
Harbour catchments	Aotea, Kawhia, Raglan	Harbour catchment areas
West Coast sub-catchments	33 sub-catchments	Sub-catchment areas
Factors		
Sediment	Updated sediment load estimator for New Zealand	Generated sediment yield estimate for reach-watersheds.
	CLUES (WANSY revised) sediment generated	Generated sediment yield estimate for reach-watersheds.
	NZEEM® sediment generated	Generated sediment yield estimate for reach-watersheds.
	SednetNZ sediment generated	Generated sediment yield estimate for reach-watersheds.
Hillslope erosion	NZLRI erosion type, and severity	Identifies areas of hillslope erosion; areas of NZLRI hillslope erosion types with slight to severe severity.
	Highly Erodible Land (HEL) landslides and earth-flow	Identifies areas of hillslope erosion; HEL identified areas of landslides and earth-flow.
Stream-bank erosion	NZLRI erosion type and severity	Identifies areas of streambank erosion; areas of NZLRI streambank erosion with slight to severe severity.
	SedNetNZ streambank erosion sediment generation	Identifies areas of streambank erosion based on generated sediment yield.
Vegetation Protection (land cover related land use pressure)	LCDB v5.0 land cover and NZLRI Land Use capability classification criteria	Identifies where land cover is considered less than the land's capability; LUC 7 and 8 in pasture.
Stock intensification (stock related land use pressure)	AgriBase™ stock unit density	Identifies where stock unit density is considered greater than the land's capability; Stock unit density 17 to >35 SU on LUC classes > LUC 4.
WRC works	WRC compartments	Identifies areas of soil conservation work (retirement and planting).
	WRC fencing	Identifies areas of soil conservation work (fencing).

7.4 Mitigation criteria for the West Coast

The mitigation criteria including mitigations used, costs, and reductions are provided in Table 13.

Table 13. Mitigation criteria (mitigations, costs, and reductions) for the West Coast prioritisation assessment.

Factor	Mitigation placement criteria	Mitigation cost criteria	Mitigation reduction criteria (% reduction)
Riparian Protection	Fence 75% of unfenced bank length	Fencing @ $20 per m	Sediment: 60 % Nitrogen: 10 % Phosphorus: 30 % E. coli: 20% Reductions are based on a mix of fencing and planting.
Riparian Planting	50% of newly fenced will require planting	Native planting @ $37,000 per ha (based on WWRRS)	
Soil Conservation – LUC 6e	South West Coast: 30% 6e requires treatment 20% poles 10% plantation North West Coast: 20% 6e requires treatment 10% poles 10% plantation	Pole and plantation planting: @$3000/ha	Sediment: 60 % Nitrogen: 0 % Phosphorus: 10% E. coli: 0% Assumes that there is no change in stock unit density.
Soil Conservation – LUC 7 land	20% plantation 80% revert 80% perimeter fencing	Plantation planting: @$3000/ha Fencing: @$25 per m	Sediment: 60 % Nitrogen: 70 % Phosphorus: 80 % E. coli: 80 % Assumes stock are excluded.
Soil Conservation – LUC 8 land	100% retirement 75% perimeter fencing	Fencing: @$25 per m	Sediment: 60 % Nitrogen: 10% Phosphorus: 30 % E. coli: 20 % Assumes low stock unit density on LUC 8 pasture that is retired.
Additional erosion outside LUC 6e, 7 and 8 land	7.5% of erosion prone land requires stabilisation	Erosion stabilisation: @$8k per ha	Sediment: 60 % Nitrogen: 0 % Phosphorus: 10 % E. coli: 0 % Assumes that there is no change in stock unit density.
Protecting indigenous vegetation bordering pasture	25% of indigenous vegetation bordering LUC 6e in pasture requires fencing; LUC 7 and 8 covered in other mitigations	Fencing: @$25 per m	Assumes minimal reductions are likely, or reductions difficult to calculate.

7.5 Outputs

7.5.1 Introduction

The outputs for the West Coast prioritisation assessment includes maps for individual factors with data normalised and ranked for the West Coast management zone, harbour catchments, and for sub-catchments. The individual factor maps collectively total 333 maps and are not presented in this report. Given the large number of maps created, maps are usually stored on the WRC GIS drive, and are available on request through the GIS Team at WRC.

The outputs presented for the West Coast example in this report are not exhaustive (i.e. not all possible outputs are presented). Examples include key issue (soil conservation and water quality) maps and graphs for the West Coast management zone (including sub-catchments) and the harbour catchments (including sub-catchments), sub-catchment cost tables, sub-catchment reduction tables., and examples of summarised data.

7.5.2 Soil conservation and ranked factor score outputs

The two main outputs for the ranked scores for soil conservation and water quality include maps and graphs. For this West Coast example, maps and graph examples are provided for all sub-catchments in the West Coast management zone as a whole (Figures 6 and 7), and for the three harbour catchments (Figures 8 and 9).

The rankings for the combined factor scores contributing to the soil conservation key issue for the three harbour catchments (Figures 8 and 9) have been normalised within harbour catchments as opposed to being normalised across the region or West Coast management zone as a whole. This provides the relativity required to make prioritisation trade-offs within each of the harbour catchments.

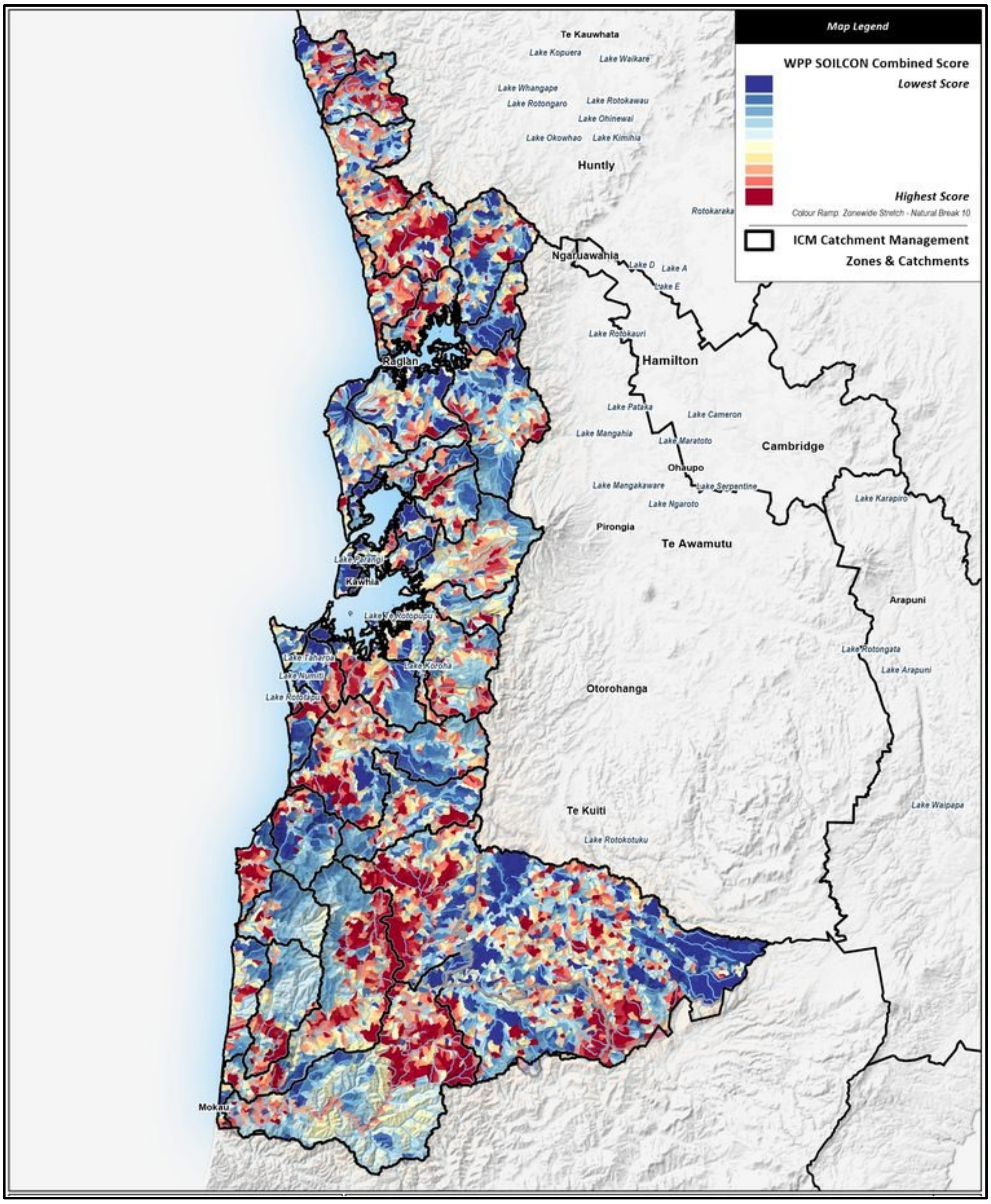

Figure 6. Map of the ranked soil conservation key issue scores for the sub-catchments in the West Coast management zone.

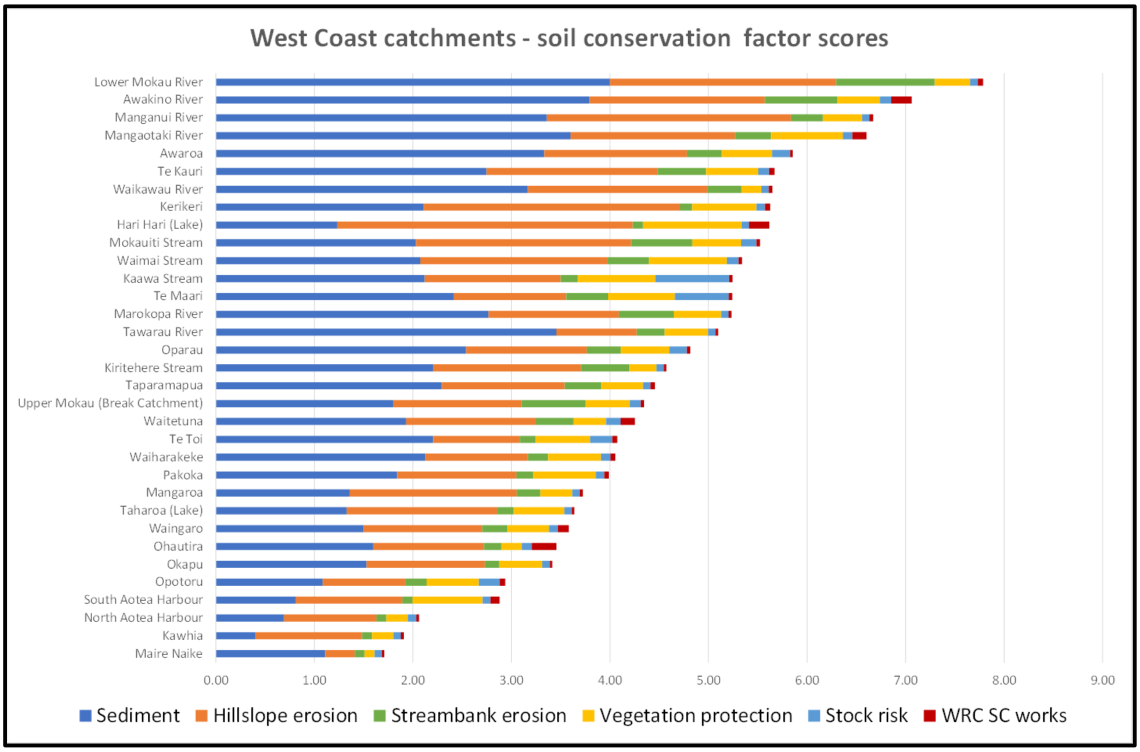

Figure 7. Graphs of the ranked soil conservation factor scores for the sub-catchments in the West Coast management zone.

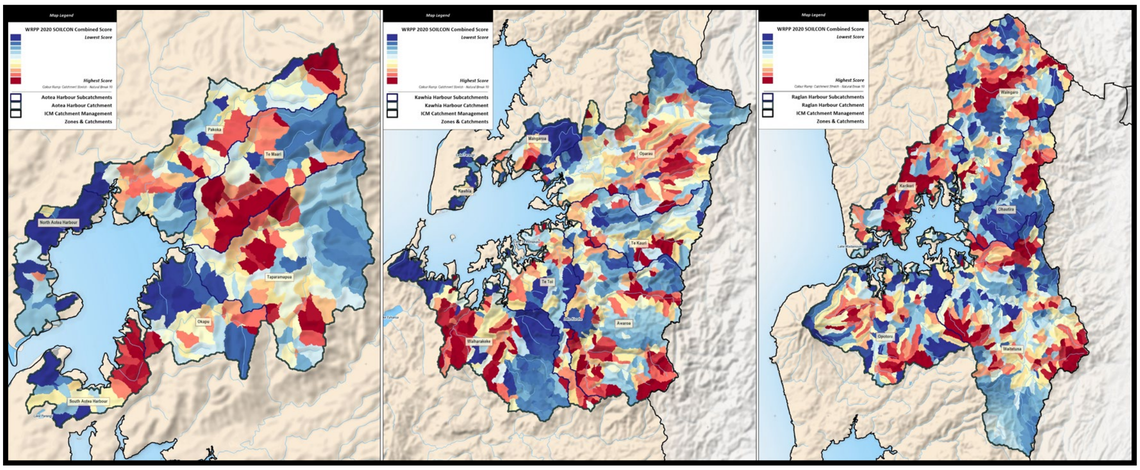

Figure 8. Maps of the ranked soil conservation key issue scores for the sub-catchments in the three harbour catchments, West Coast management zone.

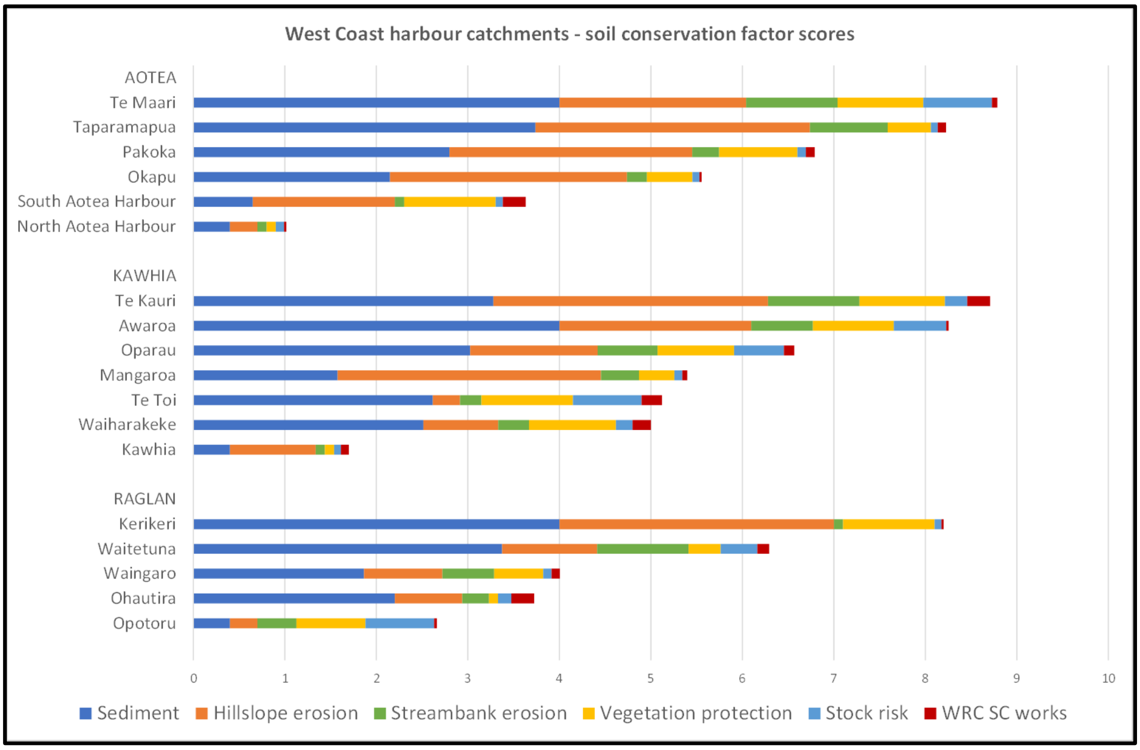

Figure 9. Graphs of the ranked soil conservation factor scores for the sub-catchments in the three harbour catchments, West Coast management zone.

7.5.3 Mitigation estimates

Estimates of the mitigations required for each sub-catchment in the West Coast management zone and for the three harbour catchments (highlighted) are presented in Table 14.

Table 14. Estimates of the mitigations required for each sub-catchment in the West Coast management zone (harbour catchment sub-catchments are highlighted).

West Coast catchments - Estimated combined mitigation requirements												
Catchment	Catchment area (ha)	Erosion treated on non LUC 6e, 7 and 8 (ha)	LUC 6e treated with poles or plantation (ha)	LUC 7 treated with plantation (ha)	LUC 8 retired (ha)	Fencing on LUC 6e (km)	Fencing on LUC 7 (km)	Fencing on LUC 8 (km)	Total hillslope fencing (km)	Total riparian fencing (km)	Total riparian native planting (ha)	Total mitigation fencing (km)
Awakino River	27465	112	688	340	62	45	295	23	364	202	51	566
Awaroa	10973	22	355	114	69	42	115	23	181	77	19	257
Hari Hari (Lake)	215	0	11	0	47	1	1	6	8	1	0	9
Kaawa Stream	6941	3	426	4	18	31	6	1	39	99	25	137
Kawhia	603	6	13	8	0	1	6	0	7	4	1	11
Kerikeri	4966	6	278	0	2	7	0	0	8	54	14	62
Kiritehere Stream	8672	30	91	121	12	9	120	6	135	49	12	184
Lower Mokau River	42141	104	692	411	42	29	311	15	355	249	62	605
Maire Naike	10608	0	0	0	0	0	0	0	0	1	0	1
Manganui River	10874	14	174	225	0	18	206	0	224	64	16	288
Mangaotaki River	22309	46	997	308	183	53	228	46	327	298	75	625
Mangaroa	2077	2	63	7	0	9	7	0	16	10	2	26
Marokopa River	23871	83	739	278	8	62	240	3	305	201	50	506
Mokauiti Stream	19456	138	479	403	61	29	309	25	363	259	65	622
North Aotea Harbour	1318	10	25	0	32	4	0	7	10	5	1	15
Ohautira	5181	4	85	9	0	14	12	0	26	13	3	39
Okapu	2014	1	70	4	0	13	5	0	18	10	3	28
Oparau	12942	60	526	76	0	42	73	0	115	124	31	239
Opotoru	10559	40	452	35	2	17	18	1	35	158	39	193
Pakoka	3564	0	143	37	0	14	24	0	38	33	8	70
South Aotea Harbour	1236	6	65	9	0	3	7	0	10	8	2	19
Taharoa (Lake)	4411	0	134	46	66	9	43	19	71	29	7	100
Taparamapua	5015	30	186	3	0	14	7	0	21	38	10	59
Tawarau River	12581	2	386	58	0	30	78	0	108	88	22	197
Te Kauri	5121	36	145	91	0	19	84	0	104	39	10	143
Te Maari	3052	3	165	0	0	8	1	0	9	30	7	39
Te Toi	4524	0	214	5	2	23	10	1	33	33	8	66
Upper Mokau (Break)	60672	441	1849	743	6	100	707	3	810	794	199	1604
Waiharakeke	8991	0	352	14	0	29	18	0	47	63	16	110
Waikawau River	8179	20	85	37	30	8	38	5	51	28	7	79
Waimai Stream	10798	45	679	10	70	25	10	10	45	157	39	202
Waingaro	12386	16	436	48	0	41	40	0	82	118	29	199
Waitetuna	17444	57	526	26	0	35	34	0	69	160	40	229
Total	**381,157**	**1,337**	**11,529**	**3,469**	**712**	**785**	**3,053**	**195**	**4,033**	**3,498**	**874**	**7,530**

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7.5.4 Mitigation cost estimates

Estimates of the mitigation costs for each sub-catchment in the West Coast management zone can be presented separately for riparian mitigations (Table 15) and hillslope mitigations (Table 16) or summed to provide total mitigation costs (Table 17).

Table 15. Estimates of the riparian mitigation costs for each sub-catchment in the West Coast management zone (harbour catchment sub-catchments are highlighted).

West Coast catchments - Riparian mitigation costs				
Catchment	Catchment area (ha)	Riparian fencing cost ($)	Riparian native planting cost ($)	Total riparian protection cost ($)
Awakino River	27465	$4,046,681.23	$1,871,590.07	$5,918,271.29
Awaroa	10973	$1,534,210.17	$709,572.20	$2,243,782.38
Hari Hari (Lake)	215	$25,797.42	$11,931.31	$37,728.72
Kaawa Stream	6941	$1,972,914.88	$912,473.13	$2,885,388.02
Kawhia	603	$81,131.53	$37,523.33	$118,654.86
Kerikeri	4966	$1,089,553.84	$503,918.65	$1,593,472.49
Kiritehere Stream	8672	$982,721.11	$454,508.51	$1,437,229.63
Lower Mokau River	42141	$4,985,357.74	$2,305,727.95	$7,291,085.69
Maire Naike	10608	$11,834.93	$5,473.66	$17,308.59
Manganui River	10874	$1,284,563.64	$594,110.68	$1,878,674.32
Mangaotaki River	22309	$5,967,286.95	$2,759,870.21	$8,727,157.16
Mangaroa	2077	$197,557.37	$91,370.28	$288,927.65
Marokopa River	23871	$4,020,434.86	$1,859,451.12	$5,879,885.98
Mokauiti Stream	19456	$5,180,548.89	$2,396,003.86	$7,576,552.75
North Aotea Harbour	1318	$97,416.34	$45,055.06	$142,471.39
Ohautira	5181	$262,042.65	$121,194.73	$383,237.38
Okapu	2014	$207,308.23	$95,880.05	$303,188.28
Oparau	12942	$2,478,958.79	$1,146,518.44	$3,625,477.23
Opotoru	10559	$3,153,247.57	$1,458,377.00	$4,611,624.57
Pakoka	3564	$654,756.89	$302,825.06	$957,581.94
South Aotea Harbour	1236	$168,253.31	$77,817.15	$246,070.46
Taharoa (Lake)	4411	$580,897.10	$268,664.91	$849,562.01
Taparamapua	5015	$768,140.87	$355,265.15	$1,123,406.02
Tawarau River	12581	$1,767,904.72	$817,655.94	$2,585,560.66
Te Kauri	5121	$778,939.87	$360,259.69	$1,139,199.56
Te Maari	3052	$595,781.90	$275,549.13	$871,331.03
Te Toi	4524	$660,180.88	$305,333.66	$965,514.54
Upper Mokau (Break)	60672	$15,886,540.07	$7,347,524.78	$23,234,064.85
Waiharakeke	8991	$1,254,163.95	$580,050.83	$1,834,214.78
Waikawau River	8179	$563,406.81	$260,575.65	$823,982.46
Waimai Stream	10798	$3,141,038.04	$1,452,730.10	$4,593,768.14
Waingaro	12386	$2,351,295.71	$1,087,474.27	$3,438,769.98
Waitetuna	17444	$3,203,009.24	$1,481,391.77	$4,684,401.01
Total	**381,157**	**$69,953,878**	**$32,353,668**	**$102,307,546**

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Table 16. Estimates of the hillslope mitigation costs for each sub-catchment in the West Coast management zone (harbour catchment sub-catchments are highlighted).

West Coast catchments - Hillslope mitigation costs								
Catchment	Catchment area (ha)	LUC 6e plantation (forest or manuka)	Erosion remediation outside LUC 6e, 7 and 8	LUC 6e fencing indigenous	LUC 7 plantation (forest or manuka)	LUC 7 fencing	LUC 8 retire and fence	Total hillslope mitigation costs ($)
Awakino River	27465	$2,063,373	$897,065	$1,126,231	$1,019,397	$7,387,232	$586,655	$13,079,953
Awaroa	10973	$1,065,843	$174,477	$1,045,862	$341,923	$2,885,874	$582,859	$6,096,838
Hari Hari (Lake)	215	$31,632	$0	$31,378	$1,256	$15,107	$143,514	$222,887
Kaawa Stream	6941	$1,276,707	$25,447	$785,943	$13,335	$147,622	$36,221	$2,285,276
Kawhia	603	$37,521	$44,836	$19,597	$22,776	$159,381	$0	$284,110
Kerikeri	4966	$833,340	$44,103	$184,262	$0	$0	$11,596	$1,073,300
Kiritehere Stream	8672	$273,465	$242,515	$227,246	$363,088	$3,002,083	$143,222	$4,251,619
Lower Mokau River	42141	$2,075,467	$834,485	$721,287	$1,233,198	$7,780,348	$383,904	$13,028,689
Maire Naike	10608	$1,423	$0	$0	$0	$0	$0	$1,423
Manganui River	10874	$522,312	$113,923	$449,084	$674,132	$5,154,541	$0	$6,913,991
Mangaotaki River	22309	$2,991,695	$368,568	$1,314,636	$923,225	$5,703,052	$1,157,546	$12,458,721
Mangaroa	2077	$188,600	$12,933	$219,473	$19,863	$180,933	$0	$621,802
Marokopa River	23871	$2,218,116	$660,824	$1,547,248	$832,807	$5,989,231	$80,654	$11,328,879
Mokauiti Stream	19456	$1,436,141	$1,103,009	$728,057	$1,209,172	$7,725,010	$614,500	$12,815,889
North Aotea Harbour	1318	$73,860	$81,283	$91,517	$0	$0	$170,236	$416,896
Ohautira	5181	$253,866	$34,181	$343,524	$27,061	$294,006	$0	$952,638
Okapu	2014	$209,088	$8,302	$327,764	$12,788	$119,716	$0	$677,658
Oparau	12942	$1,577,962	$478,171	$1,044,056	$228,237	$1,828,816	$0	$5,157,243
Opotoru	10559	$1,357,134	$320,216	$413,329	$105,763	$439,888	$31,531	$2,667,862
Pakoka	3564	$429,755	$159	$345,726	$110,731	$596,612	$0	$1,482,983
South Aotea Harbour	1236	$195,512	$45,014	$85,327	$26,109	$167,090	$0	$519,052
Taharoa (Lake)	4411	$401,474	$199	$221,654	$137,712	$1,085,762	$477,649	$2,324,449
Taparamapua	5015	$557,655	$239,241	$350,397	$7,961	$173,480	$0	$1,328,734
Tawarau River	12581	$1,157,812	$15,456	$753,085	$172,875	$1,951,974	$0	$4,051,202
Te Kauri	5121	$435,195	$289,442	$478,004	$273,573	$2,111,320	$0	$3,587,535
Te Maari	3052	$495,499	$25,357	$202,531	$1,346	$15,738	$0	$740,471
Te Toi	4524	$643,363	$56	$571,071	$16,192	$239,600	$22,465	$1,492,747
Upper Mokau (Break)	60672	$5,548,314	$3,527,902	$2,502,683	$2,227,768	$17,675,591	$71,111	$31,553,369
Waiharakeke	8991	$1,057,039	$0	$733,817	$40,980	$451,487	$0	$2,283,323
Waikawau River	8179	$255,319	$163,252	$205,462	$112,175	$942,989	$123,573	$1,802,770
Waimai Stream	10798	$2,036,441	$358,702	$634,114	$30,014	$243,886	$241,128	$3,544,286
Waingaro	12386	$1,309,117	$125,336	$1,036,101	$144,602	$1,011,863	$0	$3,627,019
Waitetuna	17444	$1,576,878	$459,759	$880,430	$77,937	$838,494	$0	$3,833,499
Total	**381,157**	**$34,586,918**	**$10,694,213**	**$19,620,896**	**$10,407,996**	**$76,318,726**	**$4,878,364**	**$156,507,113**

AOTEA KAWHIA RAGLAN

Table 17. Estimates of the total mitigation costs for each sub-catchment in the West Coast management zone (harbour catchment sub-catchments are highlighted).

West Coast catchments - Total mitigation costs				
Catchment	Catchment area (ha)	Total hillslope mitigation costs ($)	Total riparian protection cost ($)	Total mitigation cost ($)
Awakino River	27465	$13,079,953	$5,918,271.29	$18,998,224
Awaroa	10973	$6,096,838	$2,243,782.38	$8,340,620
Hari Hari (Lake)	215	$222,887	$37,728.72	$260,616
Kaawa Stream	6941	$2,285,276	$2,885,388.02	$5,170,664
Kawhia	603	$284,110	$118,654.86	$402,765
Kerikeri	4966	$1,073,300	$1,593,472.49	$2,666,772
Kiritehere Stream	8672	$4,251,619	$1,437,229.63	$5,688,849
Lower Mokau River	42141	$13,028,689	$7,291,085.69	$20,319,775
Maire Naike	10608	$1,423	$17,308.59	$18,732
Manganui River	10874	$6,913,991	$1,878,674.32	$8,792,665
Mangaotaki River	22309	$12,458,721	$8,727,157.16	$21,185,878
Mangaroa	2077	$621,802	$288,927.65	$910,730
Marokopa River	23871	$11,328,879	$5,879,885.98	$17,208,765
Mokauiti Stream	19456	$12,815,889	$7,576,552.75	$20,392,442
North Aotea Harbour	1318	$416,896	$142,471.39	$559,367
Ohautira	5181	$952,638	$383,237.38	$1,335,875
Okapu	2014	$677,658	$303,188.28	$980,846
Oparau	12942	$5,157,243	$3,625,477.23	$8,782,720
Opotoru	10559	$2,667,862	$4,611,624.57	$7,279,487
Pakoka	3564	$1,482,983	$957,581.94	$2,440,565
South Aotea Harbour	1236	$519,052	$246,070.46	$765,122
Taharoa (Lake)	4411	$2,324,449	$849,562.01	$3,174,011
Taparamapua	5015	$1,328,734	$1,123,406.02	$2,452,140
Tawarau River	12581	$4,051,202	$2,585,560.66	$6,636,763
Te Kauri	5121	$3,587,535	$1,139,199.56	$4,726,735
Te Maari	3052	$740,471	$871,331.03	$1,611,802
Te Toi	4524	$1,492,747	$965,514.54	$2,458,262
Upper Mokau (Break)	60672	$31,553,369	$23,234,064.85	$54,787,434
Waiharakeke	8991	$2,283,323	$1,834,214.78	$4,117,538
Waikawau River	8179	$1,802,770	$823,982.46	$2,626,752
Waimai Stream	10798	$3,544,286	$4,593,768.14	$8,138,054
Waingaro	12386	$3,627,019	$3,438,769.98	$7,065,789
Waitetuna	17444	$3,833,499	$4,684,401.01	$8,517,900
Total	**381,157**	**$156,507,113**	**$102,307,546**	**$258,814,659**

AOTEA KAWHIA RAGLAN

The data can be further interrogated to provide a range of data subsets and combinations. For example, Table 18 presents the mitigation cost per contaminant unit for the three harbour catchments.

Table 18. The mitigation cost per contaminant unit for the three harbour catchments.

West Coast harbour catchments - Estimated cost per contaminant unit					
Catchment	Catchment area (ha)	Sediment ($/t)	Nitrogen ($/t)	Phosphorus ($/t)	E.coli ($/Peta)
Taparamapua	5015	$294	$97	$397	$578,642
Te Maari	3052	$356	$133	$568	$939,044
Pakoka	3564	$707	$198	$1,024	$1,961,721
Okapu	2014	$676	$209	$967	$1,845,105
South Aotea Harbour	1236	$1,638	$251	$1,375	$1,701,101
North Aotea Harbour	1318	$2,946	$313	$3,418	$4,892,093
Mean catchment cost ($)		**$1,103**	**$200**	**$1,292**	**$1,986,285**
Te Kauri	5121	$978	$303	$894	$1,873,702
Awaroa	10973	$755	$240	$947	$1,499,137
Oparau	12942	$845	$236	$679	$1,162,965
Mangaroa	2077	$689	$146	$669	$1,330,009
Te Toi	4524	$403	$88	$519	$684,733
Waiharakeke	8991	$85,552	$3,618	$36,464	$32,838,659
Kawhia	603	$133	$21	$195	$149,512
Mean catchment cost ($)		**$12,765**	**$665**	**$5,767**	**$5,648,388**
Kerikeri	4966	$609	$188	$499	$1,148,912
Waitetuna	17444	$701	$181	$668	$1,673,278
Waingaro	12386	$2,969	$859	$2,166	$11,806,390
Ohautira	5181	$274	$44	$203	$435,651
Opotoru	10559	$891	$237	$870	$2,049,594
Mean catchment cost ($)		**$1,089**	**$302**	**$881**	**$3,422,765**
Mean harbour catchments cost ($)		**$5,634**	**$409**	**$2,918**	**$3,809,458**

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7.5.5 Mitigation reductions in water contamination

As with mitigation costs, mitigation reductions in water contamination can be presented separately for riparian and hillslope mitigations or collectively to provide estimated reductions for all mitigations (Table 19).

Table 19. Estimated percentage reductions in sediment, nitrogen, phosphorus, and E. coli for all mitigations in sub-catchments in the West Coast management zone.

West Coast catchments - Estimated combined mitigation reductions (sediment, nitrogen, phosphorus and e. coli)					
Catchment	**Catchment area (ha)**	**Estimated % reduction**			
		Sediment	Nitrogen	Phosphorus	E.coli
Awakino River	27465	38%	14%	23%	22%
Awaroa	10973	51%	18%	28%	25%
Hari Hari (Lake)	215	66%	15%	25%	21%
Kaawa Stream	6941	55%	19%	33%	25%
Kawhia	603	43%	13%	20%	17%
Kerikeri	4966	52%	17%	31%	25%
Kiritehere Stream	8672	26%	9%	17%	20%
Lower Mokau River	42141	25%	12%	15%	23%
Maire Naike	10608	17%	10%	22%	16%
Manganui River	10874	33%	13%	23%	24%
Mangaotaki River	22309	52%	17%	33%	25%
Mangaroa	2077	57%	20%	30%	25%
Marokopa River	23871	45%	16%	27%	23%
Mokauiti Stream	19456	46%	14%	29%	21%
North Aotea Harbour	1318	38%	9%	14%	14%
Ohautira	5181	46%	17%	24%	22%
Okapu	2014	55%	16%	26%	23%
Oparau	12942	49%	16%	28%	24%
Opotoru	10559	51%	15%	29%	21%
Pakoka	3564	52%	19%	31%	27%
South Aotea Harbour	1236	54%	17%	27%	23%
Taharoa (Lake)	4411	51%	17%	30%	25%
Taparamapua	5015	48%	15%	23%	22%
Tawarau River	12581	42%	17%	24%	25%
Te Kauri	5121	48%	15%	25%	22%
Te Maari	3052	55%	19%	31%	25%
Te Toi	4524	50%	19%	27%	25%
Upper Mokau (Break)	60672	48%	14%	27%	20%
Waiharakeke	8991	55%	20%	29%	28%
Waikawau River	8179	23%	7%	13%	16%
Waimai Stream	10798	55%	18%	33%	25%
Waingaro	12386	50%	17%	28%	24%
Waitetuna	17444	47%	14%	25%	21%
Mean % reduction		**46%**	**15%**	**26%**	**23%**

7.5.6 Summarised outputs

Summaries of the outputs can be useful for communication purposes in workshops. Figure 10 is an example of summarised WPF data used in prioritisation workshops for the West Coast prioritisation assessment.

Total zone area: 381,157 ha

33 sub-catchments

Top 5 catchments for soil conservation

- Lower Mokau River
- Awakino River
- Manganui River
- Mangaotaki River
- Awaroa

Top 5 catchments for water quality

- Mangaotaki River
- Te Kauri
- Tawarau River
- Kaawa Stream
- Te Maari

Mitigation costs

Riparian mitigations	$102,307,546
Hillslope mitigations	$156,507,113
All mitigations	**$258,814,659**

Mitigation reductions

Load reductions		hillslope/riparian
• Sediment	**335 t**	88% / 12%
• Nitrogen	**1092 t**	76% / 24%
• Phosphorus	**265 t**	63% / 37%
• E. coli	**154 Peta**	65% / 35%

% reductions		(hillslope, riparian)
• Sediment	**46%**	(47%, 37%)
• Nitrogen	**15%**	(24%, 6%)
• Phosphorus	**26%**	(34%, 18%)
• E. coli	**23%**	(31%, 14%)

Figure 10. An example of summarised WPF data used in prioritisation workshops for the West Coast prioritisation assessment.

Similarly for the three harbour catchments output data can be simplified to summarise the main points of interest for presentation in prioritisation workshops (Figure 11).

	AOTEA	KAWHIA	RAGLAN
Total area of combine subcatchments (ha)	16198	45230	50536
Mean sub-catchment area (ha)	2700	6461	10107
Ranking for soil conservation	Taparamapua Te Maari Pakoka Okapu South Aotea Harbour North Aotea Harbour	Te Kauri Awaroa Oparau Mangaroa Te Toi Waiharakeke Kawhia	Kerikeri Waitetuna Waingaro Ohautira Opotoru
Ranking for water quality	Te Maari Taparamapua Pakoka South Aotea Harbour Okapu North Aotea Harbour	Te Kauri Te Toi Oparau Awaroa Mangaroa Waiharakeke Kawhia	Kerikeri Waitetuna Opotoru Waingaro Ohautira
Hillslope mitigation costs ($)	$5,165,794	$19,523,598	$12,154,318
Riparian mitigation costs ($)	$3,644,049	$10,215,771	$14,711,505
Total mitigation costs ($)	**$8,809,843**	**$29,739,369**	**$26,865,823**
Mitigation sediment reductions (%)	50%	50%	49%
Mitigation nitrogen reductions (%)	16%	17%	16%
Mitigation phosphorus reductions (%)	26%	27%	27%
Mitigation E. coli reductions (%)	22%	24%	23%

Figure 11. An example of summarised WPF output data for the three harbour catchments used in prioritisation workshops for the West Coast prioritisation assessment.

The West Coast soil conservation example provides an indication of the large amount of data that is generated by the WPF and the way it can be grouped and simplified for presentation to a broad audience for decision making.

8 Conclusions

- The Waikato Prioritisation Framework (WPF) has been developed incrementally since 2013/14 through the Waikato Regional Prioritisation Project (WRPP) at Waikato Regional Council (WRC).
- The WPF is primarily used by Waikato Regional Council, but is of benefit to iwi partners, the Waikato River Authority, Co-governance partners, land managers, funding agencies, and communities within the wider Waikato region.
- The WPF combines multiple sourced spatial model data and applies geospatial analysis techniques to derive prioritisation rankings (scores) for managing soil conservation, at multiple scales, across the Waikato region.
- The Waikato Prioritisation Framework is dynamic in nature, providing the flexibility to adjust spatial model data inputs and criteria as new data becomes available, or as soil conservation related priorities change throughout the region.
- The WPF (and its geospatial analyses) are underpinned by a hydrologically contiguous framework and current land use layer. These ensure regional consistency in the analyses and allow for aggregation of data at different spatial scales.
- The WPF can be used to inform soil conservation works at a sub-catchment scale by identifying locations of highest risk and greatest potential opportunity for focusing and prioritising soil conservation work programmes.
- Individual factors relating to soil conservation are identified and metrics used to assign relative normalised factor scores to reach-watersheds. These factor scores can be ranked to indicate relative risks associated with the individual factors.
- Factors can be grouped to represent key issues. Three key issues have been developed for the WPF, of which two (soil conservation and water quality) are currently being used. The third issue (biodiversity) is under revision.
- Soil conservation mitigations used by WRC work programmes have been developed and can be imposed onto the WPF. A suite of six mitigations has been developed, two for riparian management, and four for hillslope management.
- Inclusion of the mitigations enables mitigation resources and costs to be estimated for areas of interest such as sub-catchments and management zones.
- Available research literature has been used to develop estimates of the likely sediment, nitrogen, phosphorus, and faecal microbe reductions achieved when implementing mitigations.
- Various data outputs are used for communicating the results of the WPF analyses. These are visually focused to enable easy interpretation by a broad audience, including WRC staff, land managers, and the community.
- The main WPF outputs include maps, graphs, and tables, which can combine and represent the output data to guide soil conservation decision making.
- WPF outputs have been used in numerous soil conservation projects at WRC since 2013/14 and provided data to support various funding applications for soil conservation.
- The WPF is flexible to allow for iterative revisions to be made as new input datasets/models become available, or as the focus of WRC soil conservation programmes change.

9 Future developments

The WRPP review by Hill (2021) provided recommendations for improving the WPF and increasing its use. These included:

- SAS provide a lead staff member to continue to champion the WRPP,
- ICM provide a lead staff member to continue to ensure the timely use of the WRPP across all zones,
- budget to be included annually in the LTP for the ongoing development of WRPP in close consultation with other WRC groups (primarily ICM),
- move to a periodic revision of the WRPP (every three to five years),
- budget be included annually in the LTP for the periodic revision of the WRPP,
- incorporate new biodiversity data back into the WRPP framework,
- investigate newly available spatial data for inclusion in the WRPP framework,
- investigate the inclusion of non-biophysical data in the WRPP framework, and
- consider rebranding the WRPP.

Of these recommendations those most relevant to the WPF are:

- Incorporating new biodiversity data back into the WPF and developing a revised biodiversity key issue,
- investigating the inclusion of newly available spatial data into the WPF,
- periodically revising the WPF (every three to five years) to incorporate the new data rather than as it becomes available, and
- investigate the inclusion of non-biophysical data in the WPF.

Incorporating new biodiversity data into the WPF to develop a revised biodiversity key issue would add value to the WPF. Including biodiversity (and potentially other non-biophysical key issues) increases the breadth of the WPF and its applications in decision making as well as enabling the assessment of co-benefits associated with soil conservation. For example, the WPF could be used to guide the placement of soil conservation mitigations such as retiring land to reduce sediment yield based on where there is also greatest biodiversity gain.

As mentioned previously, a strength of the WPF is its ability to be revised and include new input data. However, as with other models knowing which version you are using becomes an issue (e.g. as with CLUES and Overseer). To overcome this issue, periodic revision of the WPF and inclusion of a version number would clarify this.

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