Roadmap for refining rural sector mitigations in Auckland Council's FWMT- Stage 2.

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Executive Summary

Auckland Council (AC) has requested that as part of their ongoing development of their Fresh Water Management Tool (FWMT) Stage 1, a staged approach is adopted to refining rural mitigations knowledge (e.g., costs, benefits, granularity, baseline adoption and maximum adoption thereof). The FWMT State 1 is a regionalised, process-based and continuous model able to simulate contaminant and hydrology behaviour throughout the Auckland region at sub-daily resolution and for up to 107 differing sources, spanning a range of biophysical and land use characteristics (e.g., by soil, slope, cover and production type).

To support the FWMT Stage 1, an incremental approach was followed to identifying and informing application of rural mitigation options. Throughout, also engaging with key agricultural sector bodies for feedback and information thereof. In the first step, rural literature was reviewed by Muller et al. (2020a) and Muller and Stephens (2020) while Muller, Ira and Stephens (2020b) translated the literature estimates of cost and efficacy into the a Life Cycle Cost (LCC) Model for application to the FWMT Stage 1. This report is the fourth, highlighting areas for refinement of future FWMT stages in relation to the rural sector mitigations (e.g., choices of, cost and benefits for, granularity of across contaminant sources and regionalization for Auckland farm systems).

This report is intended as a discussion document. It summarises the key limitations and areas for refinement from Muller et al. (2020a; 2020b) and Muller and Stephens (2020) as well as issues highlighted as part of initial industry engagement. The report develops a roadmap for working with key agricultural sectors to develop refined evidence for the FWMT Stage 2.

The FWMT has prioritised "defensible simplicity" – adding complexity only where robust evidence exists and is warranted. The FWMT Stage 1 is already a complex model offering remarkable resolution of water quality contaminant sources, pathways, transformation and outcome on waterways (e.g., concentration, grading, loading). The FWMT is being developed, not simply to assess spread in modern-day or baseline (2013-2017) water quality, but also to identify cost-optimised strategies to drive improved water quality and/or maintain water quality in the face of increasing pressures (e.g., development, intensification of productivity and/or climate change). For that purpose, pastoral and horticultural HRUs, require a library of mitigation options to be developed. Development of a mitigation option requires three fundamental logical conditions:

1. Cost – the reduction in profit (including ongoing maintenance costs), necessary capital outlay associated with a 50-year life cycle of managing a mitigation option;
2. Effect (direct contaminant benefit) – the reduction in contaminant(s) associated with a mitigation option;
3. Opportunity – for which HRU's and contaminant(s) a mitigation option is effective, including at baseline (pre-existing) and maximum (potential).

While initial estimates have been provided for these factors in the FWMT Stage 1, there are areas across all three logical conditions that could be improved in successive versions of the FWMT.

This report is structured as follows; Section 1 describes the basis of rural mitigations simulated by the FWMT Stage 1 in national literature, Section 2 offers more detail on the FWMT, Section 3 describes the rural sector mitigations incorporated into the FWMT Stage 1, Section 4 then identifies key cross-sector (pastoral and horticultural) areas of possible improvements whilst Section 5 focusses on sector-specific areas of improvement. The report thereby provides a recommended roadmap for AC to refine rural sector scenario modelling in future iterations of the FWMT, including how to progress on each area of refinement and an indication of an initial prioritisation framework (Section 6) for further consultation.

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1 Background

Auckland Council (AC) is developing a Fresh Water Management Tool (FWMT). The FWMT is a continuous, process-based water quality model spanning the entirety of the Auckland region. The FWMT is being developed to support AC with watershed accounting, planning efforts, and implementation programmes to maintain and improve water quality. The FWMT serves dual purposes for the NPS-FM and Water Quality Targeted Rate (WQTR) in Auckland. Specifically, to fulfil freshwater accounting requirements for objective and limit-setting decision-making in the National Policy Statement for Freshwater Management (NPS-FM), and implementation requirements for AC as a unitary authority (i.e., regional and district government functions of the RMA and LGA). The FWMT is being designed to support both regional policy and planning development, as well as regional infrastructure and rural land management (e.g., Farm Environment Plan – FEP).

To accommodate dual modelling purposes (and ongoing changes to NPS-FM and Auckland Unitary Plan needs), development of the FWMT will follow a continuous improvement pathway. The FWMT Stage 1 is undergoing development and completion for 2020/21. The capability of simulating baseline (2013-2017) water quality has been developed and associated reporting produced. The capability of simulating scenario changes in land management, network management, land use, and altered climate are undergoing development. In both, adding further complexity and refinement as available and necessary to better represent land use effects on water quality is part of the ongoing development process.

In this section, we describe the basis of rural mitigations simulated by the FWMT Stage 1 in national literature. Section 2 and 3 offer more detail on the FWMT and the rural options included to date in the FWMT Stage 1. Section 4 then identifies key cross-sector (pastoral and horticultural) areas of possible improvements whilst Section 5 focusses on sector-specific areas of improvement. The report thereby provides a recommended roadmap for AC to refine rural sector scenario modelling in future iterations of the FWMT, including where/whom to seek input from key rural stakeholders. Engagement with rural stakeholders is strongly recommended prior to implementation of Stage 2, given the configuration of Stage 1 has highlighted key areas of configuration that do not readily align with sectoral or wider national evidence on rural mitigations or farm systems. This discussion will help guide that engagement process.

1.1 HRU Definition

The FWMT simulates hydrology and contaminant response of land to climate and resource use, by classifying the Auckland region into unique biophysical and land use types – so-called Hydrological Response Units (HRU), each representing how hydrological and contaminant processes respond differently to variation in climate, across ~490,000 ha of land.

HRU classes are defined by combinations of land cover, intensity of use, hydrologic soil group and slope. HRU composition of across 107 classes has been assessed for 5,465 sub-catchments, to define a “static” baseline of landscape within the FWMT Stage 1. The baseline landscape has been configured to represent the state of land use for the 2013-2017 period, but being static, is generalised over time, even if varying between sub-catchments.

Overall, 20 HRUs describe the range in land to climate for pasture cover, whilst 30 HRUs characterise horticultural land responses to climate and use. Each HRU is uniquely parameterised for hydrological and contaminant processes, on a regional basis in the FWMT (i.e., land titles of equivalent class, under identical climate, are assumed to generate identical contaminant loads in equivalent runoff, interflow or active groundwater). The development of the HRU framework, including all sources of data and transformation is detailed in the Baseline Inputs and Baseline Configuration & Performance reports (see Bambic et al., 2020a and 2020b).

Whilst HRU's are intended to represent variation in land use, HRU classes do not readily align with the wider national literature on rural mitigations. For instance, differing pastoral land use by stocking rate intensity but not by stock type, i.e. dairy or beef cattle. Therefore, in the previous reports on the rural sector mitigations (Muller et al., 2020a; 2020b; Muller & Stephens, 2020), alignment was needed between the literature and HRU groups (see, Muller at al 2002b). This is covered in further detail within Section 2.4.

1.2 Literature Review (Muller et al., 2020a; Muller & Stephens, 2020)

Rural mitigation literature was reviewed by Muller et al. (2020) to provide an indicative set of bundled mitigation options and edge-of-field (EOF) mitigation options for FWMT Stage 1, across pastoral and horticultural land uses, for total nitrogen (TN), total phosphorus (TP), sediment (total suspended sediment - TSS) and *E. coli.* For each, identifying a range of cost and benefit estimates from national literature. A key finding was the limited available information specific to Auckland climate, landscape and farm systems. However, the national literature was able to be queried to discriminate the cost of mitigation into capital, maintenance and replacement costs as well as change to operating profit (where relevant). Efficacy metrics were typically presented for farm systems mitigations as changes in loads, often from the root zone and assumed to represent an equivalent reduction when expressed to HRU – noting HRU yields are attenuated for processes to the edge-of-stream (e.g., beyond rootzone).

Muller and Stephens (2020) was an extension to Muller et al. (2020a), providing detailed estimates for riparian management options, including for fence only, fence and setback, setback only, planted and grassed variants. The recommended cost and benefits assigned were limited by the literature for setback options to 1 m and 5 m variants – a test of "reasonable assurance" finding insufficient evidence of how efficacy varies with setback distance, but that costing information was otherwise able to support alternative setback options.

1.3 Incorporation of rural sector mitigations in to the LCC Model and FWMT (Muller et al., 2020b)

Outputs from both Muller et al. (2020a) and Muller and Stephens (2020), were combined into the final suite of rural mitigation options, associated costs and benefits, and rules for application to the HRU framework. Costs were then applied to a Life Cycle Cost (LCC) model for inclusion into the FWMT Stage 1 (50-year annualised cost, discounted to 2%, 4% and 6%). The LCC model is described in Ira et al. (2020).

Importantly, pastoral and horticultural practice changes inclusive of good farming practices and deintensification, were "bundled" and tiered into a sequential hierarchy of increasing difficulty to implement (e.g., greater cumulative cost and effect). Bundles included M1, M2 and M3. Bundling was recommended to enable approximation of a diverse and variable mix of practices or choices available to all farms throughout the region. Bundling approaches are commonplace in regional planning for the NPS-FM, precisely for their ability to represent highly variable decision-making in a generalised manner (i.e., that when scaled to numerous farms offers a general effect and cost estimate). A limitation though remains the precise actions of those available for M1, M2 and M3 on any farming property is not prescribed.

Other rural options included edge of field (EOF) mitigations including, regenerating natural wetlands (small, large), detainment bunds/sediment traps, riparian management, space planting of erosion control trees (poplars) and land retirement.

2 FWMT Modelling Background

2.1 Stage 1

The FWMT is a continuous, process-based water quality model spanning the entirety of the Auckland region, both rural and urban land uses. The FWMT is being developed to support AC with watershed accounting, planning efforts, and implementation programmes to maintain and improve water quality. The FWMT serves dual purposes for the NPS-FM and WQTR. Specifically, to fulfil freshwater accounting system requirements, decision-making and implementation requirements for AC as a unitary authority (i.e., regional and district government functions of the RMA and LGA). The FWMT is therefore required to support both policy development and infrastructure planning.

The FWMT scope includes both current (2013-2017) and future state freshwater accounting, region-wide at sub-catchment scale via continuous process-based modelling (i.e., to reasonably foresee the effects of targeted investment, development and climate change on freshwater quality, integrated across the Auckland region).

Future state modelling in the FWMT is undergoing development of a mitigation library incorporating the effects (impacts) and costs of various interventions, spanning source control through to targeted devices. The FWMT spans both urban and rural landscapes and stream environments in the region, with development ongoing for both urban and rural cost and impact information suited to HRU's. HRU's are the minimum accounting unit in the FWMT, effectively the landscape types divided into varying covers, impact (intensity of use), slope and soil groups (see Section 2.4). There are in excess of a 100 uniquely represented contaminant sources, across the mix of contaminants process-modelled continuously (at 15-min increments) by the FWMT – the FWMT is at the time of writing, the most sophisticated and advanced water quality accounting framework developed by the US-EPA and based on open-sourced frameworks peer-reviewed for international regulatory use.

The FWMT scope is supported by an iterative build to accommodate revisions to national policy statements, improved regional evidence (including monitoring datasets) and community engagement in decision-making. For Stage 1, the FWMT scope is limited to accounting for six contaminants in varying forms (dissolved, total): N, P, Cu, Zn, TSS and *E. coli*. Of these, only total forms are simulated for loss from land whilst instream physicochemical and plant processes are simulated instream to speciate total into dissolved and particulate forms. Those total forms are regionally configured for 107 unique HRU's whose composition varies uniquely again across 5,465 sub-catchments spanning ~490,000 ha. Given the lack of equivalent enriched heavy metal (Cu, Zn) inputs to rural land, both Cu and Zn processes on rural HRU's are represented by TSS losses and transport. Hence, this report focusses only on benefits of rural mitigations for TN, TP, TSS and *E. coli*.

The Stage 1 FWMT is also limited in scope to direct accounting from land to stream, lake and coast environments, direct accounting instream (e.g., contaminants continuously transformed for instream processes), and indirect accounting of contaminant effects in-lake (e.g., contaminants transformed to steady-state lake outcomes on TN, TP, Chl-a and SD via optimised Vollenweider equations – Abell and Van-Dam Bates, 2018) or in harbour (e.g., to coastal hydrodynamic models).

Accommodating the FWMT's ambitious scope for a process-based and comprehensive (continuous, region-wide, sub-catchment and diverse HRU-resolved) freshwater contaminant accounting model, is not feasible within a short timeframe and single modelling stage. Instead, a prioritised and iterative approach underpins the FWMT development, of both baseline and scenario capability (e.g., for concentration and/or load grading and optimisation).

Development of Stage 1 FWMT commenced in November 2017 using a diversity of monitored data collected up to 30th June 2017, with a multi-year and incremental programme for Baseline and Scenario Modelling. Stage 1 FWMT current state capability is anticipated for delivery by early 2020 and scenario state including optimisation capability, by late 2020.

2.2 FWMT future builds

Accommodating the FWMT's ambitious scope for a process-based and comprehensive (continuous, region-wide, sub-catchment and diverse HRU-resolved) freshwater contaminant accounting model, is not feasible within a short timeframe and single modelling stage. Instead, a prioritised and iterative approach underpins the FWMT development, of both baseline and scenario capability (e.g., for concentration and/or load grading and optimisation).

An iterative approach enables the FWMT to better accommodate (ongoing) changes to the NPS-FM, inform a targeted monitoring programme for greater understanding of freshwater contaminant processes, incorporate such data in revised configuration (for improved performance) and provide an increasingly strengthened evidence base for freshwater objective-setting, limit-setting and implementation decisions.

Design and development of Stage 2 FWMT will occur in response to delivery, engagement, policy, regional planning and operational planning uptake of Stage 1 output. Scenario and sensitivity testing using Stage 1 FWMT will proceed only after development is complete (Figure 1Figure 1).

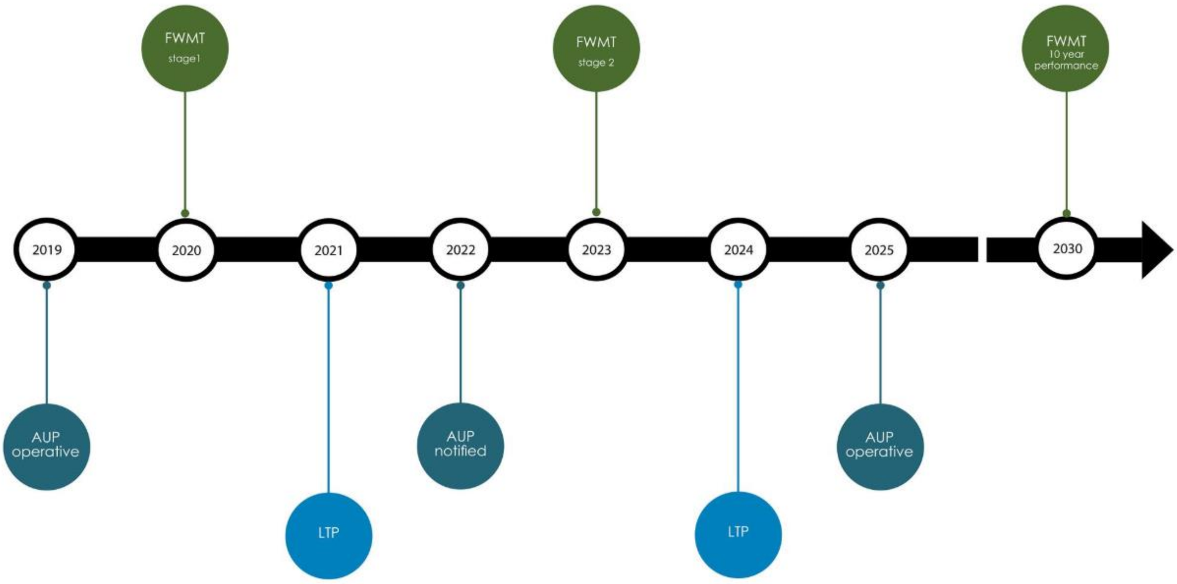

Figure 1: Delivery timeline of the FWMT through three iterative stages, with consistent scope between to deliver both baseline and scenario evidence on freshwater quality attribute states under existing and alternate management actions.

Future FWMT stages (2, 3) might implement changes to:

- Configuration of land uses – inclusion of groundwater processes (e.g., physiographics [Rissman et al., 2019]) or sectoral classifications of farm systems (i.e., to better discriminate variation in sectoral mitigation opportunities, costs, benefits or baseline adoption).
- Additional aquatic environments – expansion of processes to estuaries, lakes and/or groundwater.

- Additional contaminants or processes – accounting for gross pollutants, physicochemistry (dissolved oxygen, temperature) or ecological responses (e.g., macroinvertebrates, periphyton, macrophytes, fish).
- Sub-regional configuration – reconfiguring HRU processes on a watershed or catchment basis.
- Expanded mitigation choice – increasing the diversity of mitigation options (e.g., either new options and/or greater granularity of existing options to HRUs).
- Benefits assessment – to enable prioritisation of management strategies for more than cost.

2.3 LCC Model

Detail on the LCC model can be found in Ira et al. (2020). Only a high-level overview is provided here. LCC are used by the FWMT to perform cost-optimisation of mitigation scenarios. LCC include the sum of acquisition and ownership costs of an asset over its life cycle from design, construction, usage, and maintenance through to renewal or disestablishment (Figure 2). A cradle-to-grave time frame is warranted because future costs associated with a mitigation measure are often greater than the initial acquisition cost, and may vary significantly between alternative solutions (e.g., between grey and green infrastructure – Australian National Audit Office, 2001).

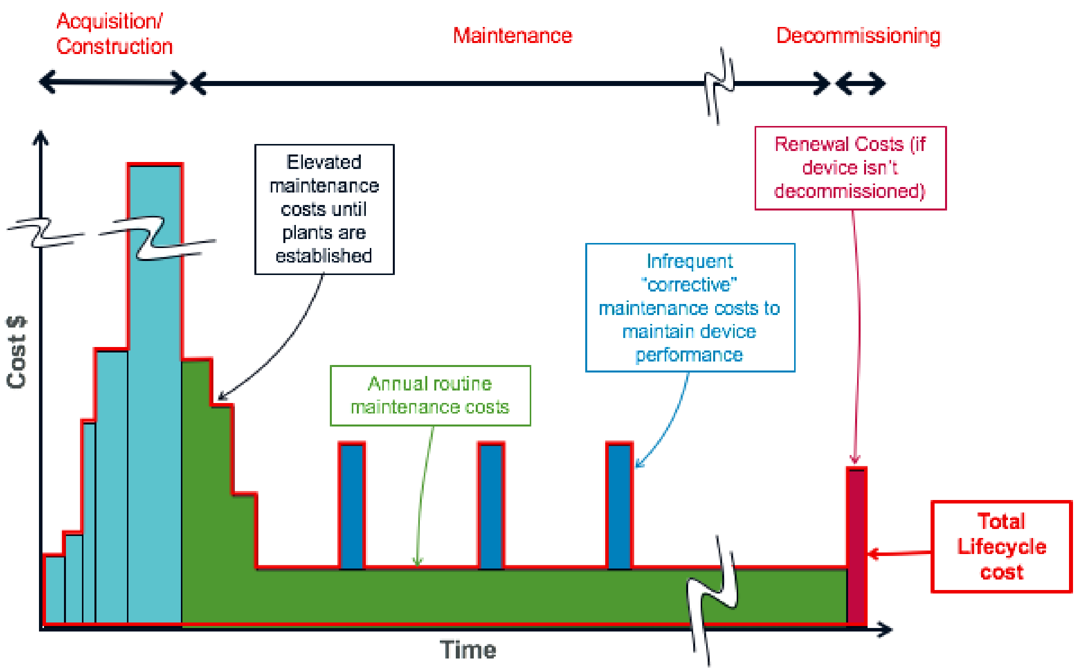

Figure 2: Phases in the life cycle of stormwater interventions and potential long term costs (Ira et al., 2020)

A robust LCC model has been developed in general accordance with the Australian/New Zealand Standard (4536:1999) for LCC. The structure of LCC models is equivalent for all mitigations (across rural and urban sectors), with following assumptions made for FWMT Stage 1:

- Default unit cost values in each of the rural LCC models are from Muller et al. (2020a) and Muller and Stephens (2020), and applied to HRU groups as per Muller et al. (2020b);
- A 50-year period has been used for costing to provide consistency with urban interventions (e.g., support integrated modelling of urban and rural water quality management in line with NPS-FM requirements – Policy 4 [MfE, 2019]);
- LCC are available for 2%, 4% and 6% discount rates, as recommended by Auckland Council's Chief Economist Unit (Ira et al., 2020);

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- Base date for all LCC is 2019 and costs are New Zealand dollars (e.g., capital, maintenance, operating profit or opportunity cost);
- LCC exclude goods and services tax (GST);
- Total acquisition cost (TAC) includes an overhead and indirect cost factor of 17.5% of the construction cost – accounting for time needed to plan, consent or implement potential mitigations, and equivalent with overhead costs for urban interventions of 15% - 20% [Ira and Simcock, 2019]). TACs are only included with EOF and land retirement rural options (i.e., not included with bundled mitigations as these lack capital costs);
- Construction costs are allocated in the first year of the LCC model with renewal costs included as appropriate in future years (e.g., fencing renewal is costed at year 1 and 26 for a 25-year lifespan). Maintenance costs are allocated for all other years. For rural options, either opportunity cost (from retiring land in perpetuity for EOF and land retirement) or reduced operating profit (from farm system changes in bundled mitigations) is considered annually.

Annualised output from the LCC model offer indicative costs; variation can be expected in those for mitigations when applied but whose central cost should be similar. Hence, comparative accuracy will be far greater than accuracy in absolute cost, supporting use in optimisation assessments. LCC allows "like for like" comparison of the full spectrum of costs between mitigations (e.g., outlay, maintenance, opportunity or profit cost). However, LCC assessments require further assumptions on the feasibility, timing, uptake or optimisation of interventions in specific location(s), or about financing, governance or distributions of costs for particular catchments or activities. **The latter are considered key areas of "scenario configuration" for later development** (e.g., when applying LCC estimates here to the FWMT Stage 1).

2.4 HRU Framework

HRU classes are defined by combinations of land cover, intensity of use, hydrologic soil group (HSG) and slope. Overall, 20 HRUs describe the range in pastoral land responses to climate and use, whilst 30 HRUs characterise horticultural responses to climate and use. The rural productive HRUs are split by the following categories:

- Land cover
    - Pastoral
        - Intensity –
            - less than 10 stock units per hectare (low),
            - more than or equal to 10 stock units per hectare (high).
    - Horticulture
        - Intensity –
            - Low Impact Horticulture - Orchards & idle fallow[1],
            - Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture
            - High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses
- Soil and slope were also separated and were consistent between pasture and horticulture:
    - HSG
        - A+ that are "very high infiltration" soils of "volcanic geology, medium to high soakage", highest free-draining soil types;
        - A that are "high infiltration" soils of "sand/loamy sand/sandy loam"
        - B that are "moderate infiltration" soils of "silt/silt loam/loam"

[1] Noting the terminology is confusing in that "orchards" are accounted for in other impact classes with any remaining land identified by LCDB4 as of orchard but lacking Agribase information to qualify as such, then assigned into the idle fallow HRU.

    - C that are "low infiltration" soils of "sandy clay loam"
    - D that are "very low infiltration" soils of "clay loam/silty clay loam/sandy clay/silty clay/clay"
- Slope (defined from region-wide LiDAR) –
    - less than 10% (~6 degrees; Low-Slope), flat to rolling land
    - greater than or equal to 10%, rolling to steep land (High-Slope).

Several rural HRU classes and groups are not well-aligned to the literature – either to cost, benefit and/or variation in mitigation opportunities (e.g., baseline adoption rates, max potential extent). Aligning HRU groups with the literature required adjustments in Muller et al. (2020b – see Table 1). These are summarised below, with recommendations in **bold** for improved FWMT scenario modelling:

- Five HSG have been grouped into three broader drainage classes to align with the literature: A and A+ (free draining), B (moderate draining), and C and D (poorly draining).

- Slope classes used for the FWMT were aligned to flat-to-rolling land (<10% or ~6 degree slope) and rolling-to-steep land (≥10% or ≥7 degree slope). The rural mitigation literature often utilised differing slope classes, particularly for fencing costs. For instance, the Agribusiness Group (2016) classed slope as flat (up to 7 degrees), rolling (between 7 and 16 degrees) and steep (between 16 and 28 degrees). Fencing costs are nearly doubled for equivalent length and fence type on steep land. For application of riparian management, further analysis is needed to determine the slope of land on stream buffers and then generalised by HRU group (e.g., low impact pasture, high impact pasture). **Reconfiguration of rural HRU's to incorporate more than one slope class, at both 7 and 15 degrees, would help better align to the literature.**

- High Impact Pasture (>10 SU/ha) has been split into dairy and sheep and beef groups given markedly differing mitigation cost (e.g., operating profit, mitigation outlay) and contaminant benefit (e.g., varying contaminant reduction effects of equivalent interventions). This is consistent with the adjustment made in Muller et al. (2020b). This adjustment reflects a high likelihood that sheep and beef farms of more than 10 SU/ha exist in the North Island. For instance, Beef+LambNZ Economic Farm Survey noting that intensive finishing farms in the Northern North Island possessed an average SU/ha of 12.6 (2018-19) (Beef+LambNZ, 2020). The split has been applied to all High Impact Pasture on a 69:31 ratio for dairy versus sheep and beef (e.g., equivalently to all sub-catchments; see Muller et al., 2020b). **Spatially resolved information on the locations and types of farms throughout the region (not simply of pasture) would improve the ability to optimise management in watersheds with differing composition of high impact pastoral activities (e.g., varying ratio of dairy to sheep and beef)**.

- Both High and Low Impact Pasture HRU groups are assigned mitigation cost, benefit and opportunity information from bovine or mixed bovine-ovine farm studies. No other pastoral sectors are explicitly recognised (e.g., deer, pig, horse). Non bovine or ovine farms account for <10% by of livestock business numbers in Auckland (and likely, far less by extent) (StatsNZ, 2017). Whilst likely of minor regional effect on scenario modelling, **future revisions to the FWMT would benefit from delineating areas where cattle-pastoral farming is less representative of wider pastoral business.**

- In addition, for pastoral land uses differences in practices should be considered. For example, the practices, mitigation opportunities and associated costs and benefits are likely to be different across significant differences in farm system types even within land use types used in the FWMT Stage 1 (dairy, sheep and beef with more than 10 SU/ha or sheep and beef with less than 10 SU/ha). For example, the FWMT Stage 1 did not consider high intensity dairy farms versus low intensity dairy farms, or sheep and beef farms with different stock class ratios (beyond the delineation at 10 SU/ha, and acknowledging that for farms with more than 10 SU/ha they are likely to have more beef than sheep stock). **Considering differences in these farm system types would improve future iterations of the FWMT.**

- Low Impact Horticulture (idle, orchards and fallow) was assessed in Muller et al. (2020a) from kiwifruit returns. AC has since indicated that kiwifruit orchards are accounted for within the High Impact Horticulture HRU. There is consequently a lack of reasonably assured mitigation information for idle land, fallow land and "other" orchards (e.g., exclusive of berry fruit, stone fruit, pip fruit, kiwifruit, other fruit and nuts – accounted for in Medium and High Impact Horticulture). To ensure inclusion within decision-making on interventions, the Low Impact Horticulture HRU costs and benefits were assigned from (identical to) Medium Impact Horticulture. Doing so likely inflates Low Impact Horticulture costs within the FWMT Stage 1 (e.g., carries greater opportunity cost) and possibly, results in greater or lesser benefit (e.g., as based on other horticultural opportunities). However, the decision is likely to have marginal effect on scenario optimisation as Low Impact Horticulture accounts for <1% of any watershed area and also, <1% of edge-of-stream contaminant loads for all six contaminants simulated by the FWMT (see Bambic et al., 2020). **Low Impact Horticulture should be separated out from Medium Impact Horticulture if possible in future iterations of the FWMT.**

- High Impact Horticulture in Muller et al. (2020a) and Muller et al. (2020b) report are both based on vegetables, for which there is more publicly available, reasonably assured evidence on contaminant losses, mitigation cost and mitigation effectiveness. Consequently, much of the inter and even intra-sector variation in cost-benefit and opportunity to mitigate contaminants, is not captured by the HRU grouping information used by the FWMT Stage 1. For example, the applicability of vegetated buffer strips for tree crop orchards is likely to be much lower than on vegetable cropping (i.e., given lower presence of bare ground). **Improved resolution of the Medium and High Impact Horticulture HRU group, distinguishing areas of vegetable cropping and orcharding, would improve the costing and benefits assessments of scenarios, given their markedly differing practices and opportunity costs (e.g., create sub-groups of Medium and High Impact Horticulture, if there is evidence for differing practices, costs and benefits).** Improved sector-specific information on horticultural mitigation choices, costs, benefits and opportunities would improve the central estimates used by HRU groupings (e.g., even without refining HRU groupings further).

Table 1: Summary of HRUs used in Muller et al. (2020b)

Land cover	Intensity	Soil group	Slope[1]
Pastoral	Less than 10 SU/ha (assumed to be sheep and beef farms)	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
	Sheep and Beef - More than 10 SU/ha	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
	Dairy - More than 10 SU/ha	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
Horticulture	Medium Impact Horticulture – Arable, citrus, fodder, nuts & viticulture (Includes Low Impact Horticulture – Orchards, idle & fallow, and is based on an arable farm model)	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep

1. Slope is based on flat to rolling = <6degrees and rolling to steep = >6degrees in FMWT- stage 1, but flat to rolling = <16degrees and steep = 16-28 degrees for fencing costs in Stage 1.

3 FWMT- Stage 1 Rural Sector Mitigations

This section briefly highlights the mitigations that were included in the FWMT- Stage 1. For a detailed description and results see Muller et al. (2020a; 2020b) and Muller and Stephens (2020).

Rural mitigations span source controls (changing diffuse contaminant losses from large areas of HRU) to edge-of-field mitigations (EOF; reducing diffuse contaminant loss from localised areas and/or intercepting diffuse contaminant losses from large areas of HRU albeit on a localised area).

3.1 Bundled mitigations

Bundled mitigations (M1, M2 and M3) represent a mix of mitigation actions applied to farm management and/or farm systems to lower contaminant yields to waterways. The FWMT Stage 1 defines bundles from existing literature without refinement to Auckland region; no reasonably assured farm-system modelling or surveyed information was available. **Collection of farm survey information about practices and activities, and regionally-tailored farm modelling is recommended, to inform baseline bundle adoption rates and improve bundled cost-benefit information used by the FWMT.**

The three mitigation bundles utilised by FWMT Stage 1 are:

- **Mitigation bundle M1** - essentially the practice change and minor system change that might be considered to represent GMP (that could be expected to be identified by and implemented as a result of a farm environment planning process). These will vary across farm types (dairy, horticulture & sheep and beef) and align with the generally accepted position of M1 being low cost and [relatively] easy for adoption on farm.
- **Mitigation bundle M2** - this will represent a combination of less costly bundled system changes and de-intensification and be cumulative of the M1 options – i.e. M2 is applied in addition to, not instead of, M1**.**
- **Mitigation bundle M3** - same as M2 but more expensive or challenging system changes, and/or further de-intensification, again cumulative of the mitigations in M1 and M2.

Bundles were defined for six HRU groupings – Low Impact Sheep and Beef; High Impact Sheep and Beef; High Impact Dairying; Low Impact Horticulture; Medium Impact Horticulture; and High Impact Horticulture. The dairying bundles were split by soil type in M1 (e.g., poor, moderately-draining, free-draining and combined) and by contaminant at M2 and M3 (e.g., into N, P and combined). The literature limited the granularity of bundles – being more detailed for dairying practice and system changes in terms of mitigation benefit and cost. As above, **farm modelling of representative farms within sectors and across biophysical gradients in Auckland will help** determine whether more granularity if required and beneficial (i.e., some sectors may not experience marked difference in cost, benefit or opportunity across soil or slope groups) **and allow for customisation of mitigations within the bundles**.

All mitigation bundles are cumulative and percentage changes should be read from a pre-mitigation base and are reported for total area (i.e., costs and benefits scaled for variation in effective area). As above, **farm surveying could help better inform the assumptions on effective area** applied to the six pastoral and horticultural HRU groups (e.g., low impact sheep and beef, high impact sheep and beef, dairying, low impact horticulture, medium impact horticulture, high impact horticulture).

The reliance on national literature for mitigation bundles aligned with the FWMT HRU groupings required numerous differing studies to be linked (i.e., for dairy, cost and benefit information for M1 is from a different study to M2 and M3). Doing so, resulted in more robust studies driving optimisation outcomes. However, as some bundle estimates are derived from differing studies, the subsequent cumulative treatment of M1, M2 and M3 increases uncertainty in scenario outputs. **Farm system modelling of regionally representative farm businesses would reduce the need to link multiple differing studies and improve confidence in scenario outputs**.

The lack of reasonably assured information on the extent of prior mitigation adoption, for each option and HRU group, was noted in Muller et al. (2020). From this, a conservative approach is recommended to assume no prior bundle adoption. Given the importance of correctly representing baseline adoption rates, to both maximum possible changes supported by M1, M2 and M3 as well as simply those in shifting current state to any target, it is **recommended that farm surveying includes assessment of practices and system setup** (e.g., offers a baseline adoption rate). Without more robust baseline information about bundles, scenario outputs must be treated cautiously as a possible over-estimate of bundle opportunity (i.e., limiting confidence in optimised scenarios relying on extensive bundle adoption).

Farm system surveying (or consultation and interrogation of industry data sets) would also inform if one bundle is suitable for all farm system types within the current HRU grouping, or if additional bundles should be developed to cover key farm system characteristics (e.g. differences within dairy, low impact sheep and beef or high impact sheep and beef farming). Doing so governs how the various bundles (and EOF) mitigations are applied (and variety of cost and/or benefit accounted for). Hence, farm surveying of land use and stocking rate would prove a valuable means of increasing confidence in assigning dairying and sheep and beef options accurately within FWMT sub-catchments, including variation of that across the region.

It is also recommended to review the assumption about proportions of High Impact Pasture in dairying (e.g., 69% thereof – see Muller et al., 2020), this could be through surveying or in consultation with industry. A reasonably assured dataset to estimate dairying extent was identified (DairyNZ & LIC, 2019) and remainder of High Impact Pasture classified as sheep and beef farming.

3.2 EOF mitigations

EOF mitigations include mitigations that intercept contaminant loss typically through retirement of land from production with limited if any system change required. The EOF mitigations included in the FWMT Stage 1 include wetlands, riparian management, detainment bunds/sediment traps and space planting of erosion control trees.

- **Wetlands** – distinguished into small and large wetlands (greater than or less than 1 ha) and applied to horticultural and pastoral HRU groups. Using two types of EOF wetlands are recommended for application to pastoral and horticultural farms, as life-cycle costs vary in relation to the size of natural wetlands (Kadlec & Wallace, 2009), however, there is no evidence base to vary the benefits which are therefore consistent between the two options. Pastoral costs included fencing (but not water reticulation) whereas horticultural costs did not, but both otherwise accounting for planting and earthworks costs, ongoing maintenance and opportunity cost from retired areas.
- **Riparian management** – riparian management scenarios are detailed in Muller and Stephens (2020). These included stock exclusion only for pastoral HRU groups (fenced and grassed 1 m setback) and 5 m buffer options for horticultural and pastoral HRU groups (grassed or planted and fenced on pastoral waterways). Stock water reticulation was costed for the stock exclusion scenario for sheep and beef riparian options (1 m grass buffer), although it is possible for break the LCC model into components for the other riparian options (e.g. extract the fencing, planting, opportunity and stock water reticulation costs). Costs included fencing capital and maintenance costs, planting capital and maintenance costs, loss of productive area and stock water reticulation costs (as appropriate to the HRU group).

- **Detainment bunds/sediment traps** – were applied to both horticultural and pastoral HRU groups, including in both capital and maintenance costs but without opportunity costs (e.g., assumed negligible). The latter assumption should be revisited following adoption, but that in the interim limited opportunity costs appear likely.
- **Space planting of erosion control trees** – were applied only to pastoral HRU groups and included capital and maintenance costs but without opportunity costs. Costs of replacement at 25 years were also considered fully offset by returns on timber from well-managed poplars. **The assumption of replacement being offset by harvesting returns, is recommended to be revisited if space planting options are prioritised in scenario outputs**.

Notably, earlier mitigation bundles often include some degree of EOF mitigation, depending on how bundles were reported by the literature (e.g., riparian management, space planted poplars). Applying EOF options cumulatively with bundled mitigations will likely result in some double-accounting of benefit but also cost (i.e., increased benefit offset by increased cost). **Opportunities to refine national information and account for cumulative implementation of EOF and bundled mitigation options should be prioritised** to improve FWMT accounting (e.g., ensure costs and benefits are more accurately linked to EOF options; ensure the opportunity for bundles and EOF is constrained appropriately to recognise for some EOF application in bundles).

As mentioned earlier, TAC included an additional 17.5% of construction costs for EOF and land retirement rural mitigations. This component of TAC accounts for time needed to plan, consent or implement EOF and land retirement options, and is presumed equivalent to urban EOF interventions of 15% - 20% (i.e., to ensure consistency for integrated catchment modelling – see Ira and Simcock, 2019). Bundled mitigations have no capital costs so include no additional component in TAC. The likelihood of additional costs for planning/design/consenting of EOF and land retirement options is uncertain given no robust information on widespread (regional) adoption of such mitigations in New Zealand. Hence, **both the need for additional costs and their equivalent magnitude to urban mitigation options, would benefit from greater evidence**.

As per bundled mitigations, the lack of reasonably assured information on the baseline adoption of EOF options warranted a conservative recommendation that no prior adoption be considered. **Farm surveying is recommended to improve understanding of prior levels of EOF adoption across various HRU groupings in the Auckland region**. Also, that **sensitivity testing be used in FWMT Stage 1** scenarios to ensure the effects of that latter assumption are understood on risks of scenarios over-predicting opportunity.

3.3 Land retirement

For Stage 1 of the FWMT, only one land retirement option was accounted for: permanent retirement to native bush without harvesting. Capital costs (including subsidies) and annual opportunity costs were included as was carbon income and carbon return filing costs. This could be applied to any land use, with the opportunity cost based on the lost profit from removing that land use. Retirement could be applied to partial or whole farms on the basis of the optimisation routines in the FWMT.

4 Cross Sectoral Areas for Further Development

This section highlights key areas which could be refined further in future versions of the FWMT. It takes recommendations from the previous suite of rural sector reports (Muller et al., 2020a; 2020b, Muller & Stephens, 2020) which are considered to apply across all rural HRU groupings.

4.1 Base land use layers

The FWMT Stage 1 land cover and impact classes are derived from LCDB4 and Agribase (2015-16 financial year). The former offered full and latter modest coverage of the region, with titles from land identified as pasture or horticulture but lacking Agribase information, being assigned into "Open Space" or "Low Impact Horticulture", respectively. In addition to possible errors in sub-catchment HRU composition, the FWMT Stage 1 is configured for a "static" HRU baseline. That is, variation in HRU extent over time is not recognised within sub-catchments. Instead, outputs represent the general mix of land cover and use within sub-catchments over the baseline period of 2013-2017. That static landscape is then subjected to seasonally (daily) varying weather, to generate continuous hydrological and contaminant responses across nutrients, sediment, heavy metals and faecal indicator bacteria.

Several base land use recommendations can be made:

1. Increasing the diversity of HRUs to recognise for more system types within existing HRU land use intensity groupings (e.g., supporting more variation in their opportunity, benefit and cost of mitigation options) and for additional pastoral sectors (e.g., deer, pigs, horses). Included is discrimination of markedly differing horticultural activities in the High Impact grouping, noting markedly different operating profits and activities (e.g., vegetable from fruit) as well as key differences in pastoral land use (such as intensity of dairy systems, and stock policies on sheep and beef farms);
2. Discriminating land uses with seasonal variation in cover or intensity of activity (e.g., cropping in particular but also wintering pastoral land);
3. Determining the extent of High Impact Pasture in dairy use and variation of that across region;
4. Determining changes to the extent of all HRU groupings (if not classes) over time and representing that change in the FWMT baseline modelling to ensure "current state" as much as scenario outputs, are accurate.

Once there is more information on the base land uses and farm systems within each HRU grouping, more representative (weighted) opportunities, costs and benefits can be generated. While there is no more comprehensive a database for land cover and use currently, than LCDB and Agribase, requirements of the NPS-FM for mandatory farm plans offer a valuable means of generating accurate, high-resolution base land use layers for subsequent stages of the FWMT. Further information on baseline operations and mitigation adoption can also be gathered from farm environment planning information, farm survey information or from information held by industry groups to better inform scenarios from the FWMT Stage 1.

The key recommendation here is to **improve the robustness of HRU definitions by improving the understanding of the base land use across the region,** this includes understanding the variation within land use types (e.g. variation within dairy farm systems) and across HRU groups (e.g. land use types grouped in High Impact Horticulture). Any further revisions to the HRU classification framework should consider working directly with industry to adopt or develop reasonably assured sectoral typologies, especially for horticultural and arable farming.

4.2 Refine HRU framework

4.2.1 Land intensity

The HRU framework generates five sub-sectoral pastoral and horticultural types for “impact” or likely intensity of production (each split over five soil groups and two slope classes). Previous reports identified this as misaligned with the rural sector, resulting in the need to split High Impact Pasture into two pastoral HRU groups, while two of the horticultural HRU groups were combined due to a lack of reasonably assured evidence on mitigations (as per Table 2).

Table 2: HRU groupings revised for FWMT Stage 1

Land cover	Original Intensity grouping	Revised Intensity grouping
Pastoral	Less than 10 SU/ha	Less than 10 SU/ha (assumed to be sheep and beef farms)
	More than 10 SU/ha	Sheep and Beef - More than 10 SU/ha
		Dairy - More than 10 SU/ha
Horticulture	Low Impact Horticulture – Orchards, idle & fallow	Medium Impact Horticulture – Arable, citrus, fodder, nuts & viticulture (Includes Low Impact Horticulture – Orchards, idle & fallow, and is based on an arable farm model)
	Medium Impact Horticulture – Arable, citrus, fodder, nuts & viticulture	
	High Impact Horticulture – Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses	High Impact Horticulture – Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses (based on a vegetable farm model)

Even with the additional pastoral group, there are likely diverse farm systems within dairy, high impact sheep and beef, and low impact sheep and beef HRU groupings. If robust information on land cover and use is generated at finer granularity than LCDB4 or Agribase permit, distinguishing that intra-sector variation should be considered. This intra-sector variation also exists for horticulture, both within the HRU grouping (e.g. the differences between tree crops and vegetable crops) and within each cropping group (e.g. the differences in vegetable crops and cropping rotations) (see Section 2.4). Better representing this land use information will likely improve the cost, benefit and opportunity estimates.

It is strongly recommended that once there is better information on the base land use within the Auckland region, the HRU framework for intensity is revised. This could be through revising the actual HRU classifications or through creating ‘sub-models’ and then amalgamating them to HRU classes or groups. For example, have sub-models based on key farm system differences for dairy farms, which are then weighted and combined to represent the dairy intensity grouping, or sub-models based on key vegetable rotations to cover vegetable growing areas, combined with sub-models for other ‘High-Impact’ Horticulture land uses such as Kiwifruit and then weighting these and combining them to represent the ‘High-Impact’ Horticultural intensity class.

Any weighting should try and acknowledge if there are any key groupings between the land use sub-models and the rest of the HRU framework. For example, is Kiwifruit located on a typically different combination of soil and slope relative to vegetable growing. This may not be possible and would be dependent on engaging with industry and accessing information at a suitable resolution. Revising HRU classification and/or developing sub-models for land uses to report up to HRU’s should be informed by key industry groups.

4.2.2 Slope

The FWMT Stage 1 HRU slope classes are defined from region-wide LiDAR, and whilst likely highly accurate for the purposes of defining sub-catchment to regional extent of land in various slopes, are based on thresholds of:

- Less than 10% (~6 degrees; Low-Slope), flat to rolling land
- Greater than or equal to 10%, rolling to steep land (High-Slope)

The latter do not directly align with sectoral farm system typologies and/or much of the literature on rural EOF and bundled mitigations. For instance, fencing costs in the literature are often delineated by the following slope thresholds:

- Flat (< 7 degrees)
- Rolling (>7 degrees and <16 degrees)
- Steep (>16 degrees and <28 degrees)

Flat and rolling categories were combined in Muller et al. (2020b) as fencing costs were broadly similar but increased substantially on steep land (due to the limitations on utilising machinery).

In Muller et al. (2020b) a simple assumption was made that all Low-Slope Pasture groups (<7 degrees) were assigned costs associated with flat-to-rolling fencing costs in the literature. However, application of steep pastoral fencing costs from the literature to High-Slope Pasture groups (>6 degrees) remains challenging. Rural scenario modelling of riparian management in the FWMT Stage 1 is **recommended to take an explicit approach, utilising information on actual slope of pastoral HRU's within a buffered distance of streams, to govern what proportion of High-Slope Pasture steep riparian costs applied to streams**.

Better understanding the slope differences at a finer resolution than Low-Slope and High-Slope would ideally enable consideration of benefits at a more granular level. However, this is constrained by the available literature on benefits and if additional granularity in slope groups is utilised the benefit estimates may need to be informed by expert caucusing in lieu of published literature.

4.3 Refining mitigation definitions (bundles)

Nearly all bundled mitigation information is derived from studies outside the Auckland region. Uncertainty remains in whether the precise effect and cost of M1, M2 and M3 would apply on Auckland farms as per other regions. **Feedback and validation are recommended on the bundle results, with rural stakeholders**. Key topics of discussion for feedback, include:

- How farm types (biophysical and farm system characteristics) from the literature studies compare to farm types in the Auckland region (see Section 4.2.1). In particular, whether the phosphorus bundle study from Southland should be expected to hold equivalent cost and benefit in Auckland.
- Whether mitigation bundles for HRU groups defined from limited studies can be applied across the full diversity of sectoral and system variation (e.g., can the dairy sector mitigation estimates be applied to all dairy farms in the Auckland region or only some sub-group of dairy farms, Low Impact pastoral studies of sheep and beef applied to deer, pig and horse farms, or High Impact Horticultural studies of vegetable cropping applied to fruit cropping).
- Are the mitigation bundles representative of the mitigation options regulation or voluntary planning mechanisms will induce? Particularly if the bundles should be re-modelled without any EOF options included and if the actions included in each bundle are aligned with what AC wants to test, particularly is the M1 bundle is representative of actions considered GMP.
- Whether granularity of bundles can be resolved finer than the six HRU groupings presented (of which Low and Medium Impact Horticulture share identical cost, benefit and opportunity for lack of information on idle or fallow land)?
- Whether alternative mitigation bundle studies are available from industry groups?

- If mitigation bundles should include more contaminant effects, especially sediment and *E. coli* that are only accounted for by dairying M1 in the FWMT Stage 1?
- Whether mitigation bundles account for actions that are not readily modelled using traditional approaches (e.g., unlikely explicitly modelled in OVERSEER, APSIM or SPASMO). For instance, the targeting of critical source areas for sediment loss.
- Are modelling protocols across mitigation studies used reasonably consistent (e.g., whether input and output prices are long term averages, what period, whether farm optimisation included)? If not, how to enable multiple studies to be linked across M1, M2 and M3? Some of this information is not explicitly clear in existing literature, and any future modelling specific to the FWMT should include detailed and agreed upon modelling protocol.

As noted, only the dairy M1 bundle accounts for sediment and *E. coli* effects. This is a consequence of the farm practice and systems changes being predominantly modelled in Overseer and Farmax (or similar software). Overseer, which considers the impact of mitigations on N and P, does not estimate the impact of mitigations on sediment or *E. coli*. **The FWMT would be improved if the bundled mitigations across all land uses could consider all contaminants**.

Engaging with sectoral bodies could identify alternative literature estimates or support new farm system modelling designed specifically for the FWMT (as was the case in studies such as Burt, Sluys & Fung, 2017; Newman & Muller, 2017; DairyNZ Economics Group, 2014; Matheson, Djanibekov, Bird & Greenhalg, 2018, which undertook farm system modelling for specific regional council processes).

4.4 Refining mitigations (EOF)

EOF mitigations used by the FWMT Stage 1 include wetlands (small, large), riparian management, detainment bunds/sediment traps, space planting of erosion control trees and land retirement. Muller et al. (2020a) noted several other EOF mitigations but which lacked a reasonably assured (robust) evidence base before adoption (e.g., dung beetles) or are too complex to accurately model (e.g. stock wintering structures). Others already included, like riparian management, could be improved with targeted studies to quantify the benefits at varying setbacks (e.g., 3 m). Reasonably assured evidence of benefits centred on 5 m buffers whilst costing information was reasonably assured for varying setbacks. Finally, should the HRU framework become diversified further to include more classes for each pastoral and horticultural sector, then variation of benefit, cost and opportunity might be needed (e.g., varying proposed estimates from Muller et al., 2020b beyond the six HRU groupings of pastoral and horticultural land).

Where there is a strong desire to include EOF mitigations that are not supported by a robust evidence base, expert opinion could be used as an alternative. This could also be used to assign relative impact and cost by the refined farm typologies (i.e. if the impact of sediment traps is the same for vegetable and tree crops). Expert caucusing could also provide evidence for the impact of the EOF mitigations used in Stage 1 on contaminants that are currently missing. For instance, the benefits of detainment bunds or sediment traps for horticultural land uses on contaminants other than sediment.

Four key questions can guide sectoral engagement on EOF mitigation configuration in the FWMT Stage 1:

1. If any additional EOF mitigations should be included – if so, what costs, benefits and opportunity thereof exist across HRU groups;
2. If EOF mitigations currently included in Stage 1 can be further refined (by farm typology or mitigation design [e.g., benefits of further buffer widths]);
3. If benefits unquantified in studies but of interest to the FWMT exist and can be estimated by expert opinion;
4. If EOF costs and benefits remain independent of bundles (e.g., continue to have the same cost and benefit when applied before or after M1, M2 or M3).

4.5 Applicability

A major limitation of the existing HRU framework and EOF mitigations is accounting for stock water reticulation in sheep and beef riparian management options (e.g., Low Impact Pasture, High Impact Pasture). The most robust estimates of latter costing are reported on a $/ha basis, without information on the lengths of waterways associated (e.g., preventing translation into $/m basis for inclusion in riparian options – Journeaux & Van Reenen, 2016). In the FWMT Stage 1, a sensitivity analysis as undertaken of including and excluding stock water reticulation costs in stock exclusion riparian options on sheep and beef farms. However, **refining the estimate of what stock water reticulation is needed would improve cost estimates in future FWMT versions.**

Other applicability estimates that could be refined include the other EOF options such as space planting of erosion control trees and what land areas they would be suitable for. If farm typologies (HRU sub-groups) are refined as per Section 4.2, then further refined evidence will be needed on costs, benefits and opportunity for simply existing EOF already applied in the FWMT Stage 1.

4.6 Adoption

There is a notable lack of data on historic (baseline), ongoing or future rates of water quality mitigation adoption across Auckland and New Zealand. Surveyed farming data is often inconsistent between regions, land uses, mitigations and/or lacking in verification, if even available beyond localised areas (Daigneault and Elliot, 2017; Our Land and Water, 2019). A strong **recommendation is that the FWMT would be improved markedly for scenario and ongoing accounting exercises, through robust surveying of mitigation implementation on horticultural and pastoral land**. Notably, any such surveys require consistent terminology linked to the FWMT mitigation library, geospatial information on the areas of farmland treated by bundles and EOF devices, dates of adoption and ongoing maintenance activity – all classified consistently over time and region.

4.7 Costs and benefits beyond the scope of FWMT Stage 1

In the FWMT Stage 1 costs for the rural sector include capital costs, maintenance costs and either opportunity costs (from retiring land in perpetuity for EOF and land retirement mitigations) or reduced operating profit across 50-years (from farm system changes in bundled mitigations).

Numerous other costs are not considered including tax, debt repayments and interest and some associated capital transactions, such as the disposal of Fonterra shares, surplus plant etc. The level of reduction in operating profit associated with insolvency of a farm business is not yet quantified for restricting FWMT scenarios (e.g., optimisation scenarios are able to run beyond thresholds in operating profit associated with a business losing viability).

The impact of changes to farming systems, especially through de-intensification and land retirement do not consider the flow on implications for jobs (both on farm and in processing, sales and supportive industries) or the economy (regional and national) from reduced profitability for farm businesses (or through increased prices for products from the rural sector). Scenarios from the FWMT do not consider how costs will differ in relation to changes in technology or factors such as regulation and international markets across the 50-year time period (e.g. changing milk prices).

Land values are not explicitly considered in the FWMT Stage 1. Currently, profit is the basis for the opportunity cost of requiring changes on rural sector farms. However, there is not a direct one to one relationship between operating profit and land value. It is complex to estimate the impact of requirements to mitigate contaminant losses from farms on land values which are influenced by the ability to change practices (e.g. intensify within a land use) or use (e.g. to other land uses). Let alone, international markets, zoning regulation, urban sprawl, amenity values, lifestyle factors and national regulation all otherwise having potential to alter land value independently of profit. Combined, it is incredibly complex to include land values in the FWMT.

Despite this, operating profit is a reasonable measure of cost to rural sector activities from requirements to achieve the NPS-FM. However, any costing output and optimised scenarios must be treated carefully to acknowledge that a key measure of cost (land value) is not accounted for.

To labour the point, the capital value of land has historically contributed to the returns from farming. In Auckland in particular a key consideration on land values is the impact of zoning regulations and the associated change from rural to urban land use. This could have more influence the land values of rural land than contaminant loss mitigations.

Similar shortcomings are evident also about benefit assessments. Notably that benefits beyond contaminant or hydrological outcomes are not estimated (e.g., carbon sequestration, amenity, biodiversity, reductions in biogenic methane emissions, cultural health value). The beneficial outcomes of improved water quality on ecological outcomes is also not directly considered (e.g., is indirectly linked through NOF guidance and grading to contaminant outcomes). Considering these types of ecosystem services (ESS) will provide a more robust picture of mitigation impacts, though they can be complex to quantify into an accounting-based model such as the FWMT.

To improve decision-making from the FWMT in future stages, additional forms of cost and benefit should be considered. This could be through the inclusion of qualitative information and narratives, additional studies on key factors such as non-market benefits, or including aspects in the model that address some of these costs and benefits (e.g. on farm, debt repayments and off farm such as jobs from the rural sector). This is considered an important consideration as these will be costs and benefits that flow through the Auckland community as a result of decisions made through the information used in the FWMT.

4.8 Others

Other areas of consideration for future versions of the FWMT include:

- TAC includes an overhead and indirect cost factor of 17.5% of the construction cost (this accounts for time needed to plan, consent or implement potential mitigations, and associated contingencies, and is based on a likely overhead cost for urban interventions of 15% - 20% [Ira and Simcock, 2019]). TACs are only applied to EOF and land retirement mitigations, and not to bundled mitigations (as these have no capital cost). Overhead and indirect TAC are taken from the urban context and is **recommended to be reviewed for relevance to the rural sector**.

- The FWMT optimised logically on cost. However, farmers may not. Despite this, using the assumption of lowest cost being the most preferred option provides a level of consistency and transparency to the model. The FWMT cannot be expected to capture all possible decisions as it is a model and thereby a simplification of reality. Trying to prioritise on farm adoption of mitigations on an alternative to lowest cost is likely to add significant complexity and increase uncertainty as preferences for farmers change over time.

- The FWMT simulates baseline and steady state outcomes of mitigation scenarios (i.e., does not simulate the transition period). Benefits associated with mitigations are therefore assumed to hold over time universally. That assumption might not hold as many EOF mitigations have only been studied in the immediate short-term, and several are likely to lessen in benefit over time without active maintenance (e.g., infilling of detainment bunds or sediment traps). Whilst costs are considered to reflect active maintenance and replacement over time, the inability to represent variation in performance will result in error when compared directly to observed changes. For instance, initial construction of several EOF mitigations on rural land might result in a short-term increase in contaminant yield. Similarly, operating profits are assumed to remain stationary over time despite likelihood of varying (e.g. international product prices or changes in input prices). In addition to costs and benefits, there is a lack of information on how adoption changes over time. While these are areas that could be refined it does become complex to access robust data on what these transition periods (or cost, benefit and adoption) may look like. Some options exist to support this, such as the ADOPT framework (Kuehne et al., 2017) for considering how adoption of mitigations may change over time.

- The ability for land uses to change is not considered in the FWMT Stage 1, except for outright land retirement to non-harvested native bush. This transition considers both the capital cost of changing land use and the change in operating profit across 50-years. Currently the FWMT can be used to consider other land uses, however only at the level of considering their base (pre-mitigation) contaminant impact and operating profit. This means the land use change cost only considers the change in operating profit associated with the change in land use and not the capital cost required to adjust infrastructure, stock, etc. Land use change has occurred since the baseline period (2013-17) and **should be included more explicitly (and robustly) in the model moving forward if scenarios considering land use change were to be run.** To include this option it would be best to utilise typical, or average, contaminant and profit levels across each land use type and include estimates of the conversion costs. Decisions on how to constrain or run land use change scenarios would need to be considered.

5 Sectoral feedback on FWMT development

This section highlights key areas which could be refined further in future versions of the FWMT. It takes recommendations from the previous suite of rural sector reports (Muller et al., 2020a; 2020b, Muller & Stephens, 2020), as well as initial conversations with rural sector industry bodies, which are considered to apply to specific rural sectors. While this is based on an initial conversation with rural sector groups. It is strongly recommended that the discussion below is considered tentative ahead of stronger engagement with rural sector industry groups and key stakeholders.

5.1 Horticulture (HortNZ)

The definition of intensity for Horticultural HRU's was felt to be misleading as would vary by contaminant. For example, tree crops (e.g. kiwifruit) have a different contaminant profile and mitigations options, cost and effectiveness, than other crops which are otherwise grouped together in High Impact Horticulture (e.g. for differences in N loss estimates by crop type, see Archer and Brookes, 2018). Likewise, in the medium impact horticulture grouping, there is likely to be a difference in contaminant yields between arable land uses and tree crops (e.g. viticulture). On this basis, labelling crops as Low, Medium and High Impact is disengaging and potentially misleading. It is recommended that HRU groupings are re-named to better align with sectoral classes and realigned to be grouped (or sub-grouped) based on equivalent contaminant yield and/or mitigation opportunity, cost and benefit (see Section 4.2.1).

Several HRU classes lacked clear definition of their configuration (e.g., fallow land with all cropped systems laying fallow for some time). The definition of HRU classes needs further refinement as the basis of engaging stakeholders and in creating more accurate land use layers, let alone correct application of mitigation options, especially for multi-year crop rotations[2] (see Sections 2.4 and 4.2).

Mitigation options can be expanded to include more horticulture-targeted choices, such as those included in Barber (2014). However, Barber (2014) appears to lack sufficient information for alignment to the HRU framework and quantify costs and benefits for LCC modelling. Hence further horticultural mitigations would benefit from field trials and/or an industry/expert panel to apply mitigation options to the horticultural HRU groups.

The use of OVERSEER for horticulture and arable land uses has been criticised (e.g., FAR, 2013) especially as it does not estimate the impact of mitigations for sediment and the crop selections are limited. Studies used in FWMT Stage 1 include those which use OVERSEER for estimating the efficacy of mitigations (e.g. The Agribusiness Group, 2014), though these often also note the limitations of using OVERSEER. Alternative modelling sources and software may provide more robust mitigation information ad should be explored for further use. This includes APSIM or SPASMO which have been used to estimate mitigations on horticultural land uses, e.g. Archer and Brookes (2018) who used SPASMO across a range of crop types in the Hawkes Bay region.

The impact of land values and potential land use change should be included given the differing values of land uses and base contaminants. This would include from groupings within the High, Medium and Low Impact Horticulture groups, between other rural land uses and from rural land uses to urban. This is explored further in Sections 4.7 and 4.8. An additional factor that needs to be considered alongside land use change and land use values is the consideration of horticulture land uses which have long term crop rotations through lease land. This includes crops which have a multi-year crop rotation (e.g. potatoes or onions) which may exist on lease land which rotates through pasture HRUs. While these are likely considered on an average

[2] For example, potatoes typically can only be grown in one place once every 6-8 years (Deverall, 2019).

basis as the base period covers a 5-year period, however, it warrants further consideration, especially in relation to capturing the costs and benefits of mitigations across crops like this. One way to include the costs and benefits of mitigating contaminant losses on these types of rotations would be to consider it as a temporary land use change. An alternative would be to average the costs and benefits over a longer term average. Another consideration in relation to this challenge is what happens to land lease and purchase values if these horticulture users change practices and for example purchase land previously leased

There was concern raised the FWMT Stage 1 only considers the on-farm impact of mitigations, it significantly underestimates the true economic of mitigations on horticulture land. In particular it excludes consideration of differences in yield which influences the price of domestic produce for regional and national consumers, it excludes the impact of mitigations on jobs and it excludes the impact of mitigation on produce quality (e.g. desired shape and sizes for produce). The significance of these impacts is discussed by the horticulture industry in various regional council process such as Deverall (2019). The importance of some of these considerations have been recognised nationally with the current NPS for Highly Productive Land which is currently under development and is largely designed to protect high food producing areas from urban encroachment. This is explored further in Section 4.7, and these impacts should be considered alongside the impact of on-farm economic impacts.

5.2 Dairy (DairyNZ)

The assumption of dairying extent was likely to be questioned, as was the assumption of equivalence across all sub-catchments (e.g., 69% of High Impact Pasture being dairy). In line with Section 3.1, both could be revisited through engagement with industry, industry data sets and/or with farm surveying across the Auckland region (e.g., as part of any Farm Environment Plan programme).

The bundled mitigation options utilised in the FWMT Stage 1 for dairy are based on three primary studies. Only one study (NIWA, 2010) differentiates results by soil type, although the other studies implicitly consider a range of soil types by nature of their methodology. The remaining two studies are based on mitigations which were targeting mitigation of a single contaminant, which means when they are transferred to the FWMT optimising across multiple contaminants is not possible. While the study that focuses on N (DairyNZ Economics Group, 2014) is based on the Waikato region which is assumed to have similar climate, soils and farm systems to Auckland, the P study (Newman & Muller, 2017) is predicated on Southland farm systems which have a very different climate and farm system. This means the results for P mitigation should be used with caution in the FWMT as they may include mitigation options (including the associated costs and benefits of these) which are not applicable for the Auckland region.

It is recommended that the dairy mitigation work should be revisited for Auckland specific dairy systems (e.g., modelling Auckland dairy farms in OVERSEER and Farmax or equivalent software). Preferably, in collaboration with the industry and with a mind to linking any industry typology with the HRU framework. Any future modelling should first confirm a consistent modelling protocol across sectors.

DairyNZ has been undertaking farm systems modelling for a variety of purposes across the country. During this, they have accumulated expertise and improved their processes and are in the process of developing a modelling methodology to estimate the impact of mitigating contaminant losses from the variety of farm systems (based on both biophysical and farm system characteristics). It is recommended that if possible, this is explored as an option to improve the mitigation bundles for dairy farms currently used in the FWMT Stage 1.

Based on initial industry engagement it was suggested that the FWMT Stage 1 does not adequately consider the transition period. This is covered in more detail in Section 4.8, but in particular the FWMT Stage 1 does not consider changes in input and output prices over the 50-year time period of the FWMT. Nor does the

FWMT Stage 1 consider how mitigations are adopted overtime. Considering how these features could be incorporated into the FWMT would contribute to a strengthened modelling tool.

5.3 Sheep and beef (Beef+LambNZ)

The FWMT is intended to utilise information on rural contaminant generation and mitigations to understand the costs of achieving various water quality outcomes. Through this, supporting AC with watershed accounting, planning efforts, and implementation programmes to maintain and improve water quality under the NPS-FM and through targeted investment (e.g., WQTR). To better support Beef+LambNZ engagement with AC decision-making, feedback was received about utilising the FWMT to explore the economic and water quality impacts of changes based upon an underlying Land Use Capability (LUC) framework. LUC classes land on the underlying Land Resource Inventory (LRI), a composite index of five physical factors: rock, soil, slope, erosion type and severity, and vegetation cover (Manaaki Whenua Landcare Research, 2020). This is commonly advocated for as a proxy for a 'natural capital' approach, whereby land is grouped based on its natural capital assets and therefore what can be produced 'naturally' from the land (beyond the addition on external inputs such as supplements and fertiliser to support the farm system).

To support any LUC-based approach to scenario modelling, the HRU framework would need to be aligned with the LRI (as a proxy for natural capital). Following this, modelling protocol would need to be developed and require decisions (which should be made in conjunction with all interested parties) such as:

- what scale is used to define natural capital (i.e. is each LUC parcel treated different or can a particular land use type occur across a combination based on the predominant grouping),
- what land uses can occur on what LUC land (including farm systems information not just base land use), and
- how will the cost and benefit of changing land uses be captured and how will the impact of the transition be considered.

Essentially the FWMT would then need to be configured to run in one of two ways. Firstly, each LUC is prescribed a desired contaminant level (across all contaminants) and then the model would either mitigate or change land use to achieve contaminant levels. Or alternatively the model is forced to apply specific land uses on each LUC grouping, though the challenge with this is that the LUC groupings are quite generic and so significant assumptions would be needed about what land uses is suitable where. For both options, reporting and costing would then be in regards to the change in contaminant yields from current land use to land uses which would occur based on the aforementioned decisions about what land use will occur on each LUC grouping (e.g., linking targets for contaminant generation less to outcome instream and more to variation between LRI groupings). While this approach is a possible extension of the FWMT in future stages, it would require further discussion around objectives and assumptions in order to ensure it adds to the desired outcomes of the FWMT and provides information to the various stakeholder groups.

As discussed in Section 4.3 there is a lack of mitigation benefit for sediment and/or *E. coli*. While this reflects limitations of the literature, improvement of the FWMT could be made by quantifying bundled and EOF mitigation benefits on sheep and beef farming for the latter contaminants. This includes improving how the cost, benefit and applicability of managing critical source areas (CSAs) are considered in the FWMT.

There is a wide diversity of farming systems in the sheep and beef sector with Beef+LambNZ officially recording data on eight different farm classes, and within each class, there is further variation in the proportion of revenue that comes from wool, sheep, cattle, dairy grazing, cropping, deer, velvet etc. (Beef+LambNZ, 2019). Concerns were expressed about whether the mitigation options (cost, benefit, opportunity) accounted for such variation through delineation into only two groups: Low Impact or High Impact Sheep and Beef. This may miss differences in farm system characteristic such as stock class ratios and stock types. This is explored further in Section **Error! Reference source not found.**2.4 and 4.2.1. **It will be**

important to test the assumptions made for the proportion of High Impact Pasture (>10 SU/ha) presumed in sheep and beef and the intra-sector variation in both low and high impact sheep and beef systems.

Validating the Low Impact Pasture (<10 SU/ha) fencing assumptions was also identified as important to uptake of FWMT Stage 1 outputs. For instance, assumptions of 8-wire fencing and stock water reticulation being necessary (Muller et al., 2020b).

In initial engagement with peak industry body for sheep and beef farmers it was recommended that consideration be given to how to include ESS into the FWMT, or consideration be given to these alongside the FWMT. This is discussed further in Section 4.7 as other industry groups also provided costs and/or benefits they would want added into the FWMT.

The FWMT Stage 1 considers land use and therefore mitigation at a land parcel level, it is not necessarily aligned to farm boundaries, and is instead dependent on the layers underpinning the HRU framework. In addition, the FWMT Stage 1 considers mitigations as their costs apply to a farm scale. However, in the rural sector sub catchment and/or collective mitigation approaches are also a potential solution. In these options, the mitigations are designed to be the most cost effective for a collection of farmers and the costs and benefits are designed to be shared in some form across those involved. An example would be a wetland situated at the optimal spot in a sub-catchment and all farms who benefit from this wetland contribute to the cost (this could be in equal shares or proportionally) and all receive some amount of benefit from the collective mitigation. The FWMT considers EOF mitigations such as wetlands at an HRU level or a 'regional' level and as such effectively captures the benefit of collective mitigations. However, from a farm perspective the costs may look different if they were considered a collective mitigation rather than each farm considering equal costs (i.e. farmers may choose to utilise a large catchment scale wetland as collective the cost is lower than that incurred if they all built wetlands or all de-intensified to achieve the same level of benefit. This is an area where further model options could be developed though it would be complex to represent choices amongst multiple 'economic parties' (i.e. multiple farmers).

6 Suggested work plan for FWMT - Stage 2

Sections 4 and 5 identified areas for further refinement in future iterations of the FWMT. It is recommended that areas for refinement are prioritized as in Table 3, incorporating any feedback to the prioritization based on feedback from rural sector stakeholders and testing of Stage 1 (i.e. prioritise those which will provide maximum value to regulatory and implementation decision-makers for added cost and complexity of modelling).

An indicative summary of Stage 2 priorities identified in delivery of mitigation costing and benefit information for the FWMT Stage 1, is produced in Table 3. The latter is intended to serve as the basis for engaging with key agricultural stakeholders on further improvements to the FWMT design, inputs and/or use by AC.

The columns related to prioritisation are defined as follows:

- Importance- Consideration of how much potential difference this will make to the results and how important the factor is for stakeholders.
- Complexity- How complex it would be to include such a suggested change in the FWMT (i.e. reconfiguring the model to be able to capture changes).
- Ability- Ability to access information or undertake the work needed to incorporate the factor into the model (i.e. more about ensuring model changes are built on robust data).

The columns are purposely assigned classes of differing terminology, recognising that overall priorities assigned to an improvement cannot yet be assessed for stakeholders, nor should be (i.e., reading across importance, complexity and ability whilst is possible but overall priority is unclear ahead of stakeholder feedback, knowledge of regulatory priorities and knowledge of operational priorities). Reading the table, green shading highlights those recommended changes of *greater* importance, *limited* complexity and *ready* ability, and red shading the inverse.

Table 3: Summary of opportunities for FWMT Stage 2 and 3 improvement (for rural accounting)

	Improvement area	Recommendation	Relevant report section	Initial prioritisation ranking (Change to FWMT approach needed)		
				Importance (Limits of accounting)	**Complexity (Degree of re-configuration)**	**Ability (Availability of data)**
1	Reconfiguration of slope classes	Reconfiguration of rural HRU's to incorporate more than one slope class, at both 7 and 15 degrees, which will allow the HRU slope classes to align with the literature on rural costs, especially fencing.	2.4, 4.2	Low (Only affects fencing)	Greater (Re-configuration of new HRUs required)	Ready
2	Refining existing HRUs (dairy and sheep and beef)	Spatially resolving the split of High Impact Pasture (>10 SU/ha) across dairy and sheep and beef.	2.4, 3.1, 4.1, 5.2, 5.3	High	Lesser	Challenging/Modest (Lack of geodata would rely on industry data)
3	Refining existing HRUs (alternative pastoral land uses)	Delineating areas where non sheep and beef or dairy pasture land uses (e.g. consideration of dairy support, deer, pigs etc.) are prevalent.	2.4, 4.1, 5.3	High	Lesser	Challenging (Lack of geodata)
4	Defining sub-groups of HRUs (pastoral)	Understanding and incorporating sub-groups of pastoral farming (e.g. types of dairy or sheep and beef farms based on key farm system differences).	2.4, 4.1, 4.2, 5.2, 5.3	High	Moderate (Re-configuration of new HRUs or breaking down the HRUs into sub-HRUs required)	Modest (Lack of geodata, but can be estimated through farm systems modelling with access to farm level data)
5	Refining existing HRUs (horticulture land uses)	Separate Low and Medium Impact Horticulture, including costs, benefits and maximum opportunity for mitigation options.	2.4, 4.1, 5.1	High	Lesser	Ready (Lack of economic data)
6	Defining sub-groups of HRUs (horticulture)	Create sub-groups of Horticulture HRUs that are better aligned to contaminant impact and mitigation cost, benefit and opportunity. (i.e. exclude and optimize separately for vegetable crops and tree crops).	2.4, 4.1, 4.2, 5.1	High	Moderate (Re-configuration of new HRUs or breaking down the HRUs into sub-HRUs required)	Modest (Would require creation of additional economic and geospatial data)
7	Mitigation bundles applied to sub-groups of HRUs	Refine mitigations bundles across sub-groups of farm types. *Reliant on improvement number 4 and 6.*	3.1, 5.1, 5.2	High	Lesser (Representing options; high to develop sub-HRUs in [5])	Modest (Requires farm-system modelling)

Improvement area		Recommendation	Relevant report section	Initial prioritisation ranking		
				Importance	Complexity	Ability
8	EOF mitigations applied to sub-groups of HRUs	Refine costs and benefits of EOF mitigations across sub-groups of farm types. This may rely on an expert panel where benefits and/or costs don't exist at the required level of granularity. *Reliant on improvement number 4 and 6.*	3.2. 4.4	Low	Lesser	Ready
9	Effective versus ineffective area	Refine assumptions on how much land use is effective versus ineffective across HRUs.	3.1	Low	Lesser	Modest
10	Refine benefit estimations of EOF mitigations	Particularly for riparian buffer widths (possibly across sub-groups of HRUs if required). This may rely on an expert panel where benefits and/or costs don't exist at the required level of granularity.	3.2, 4.4	High	Lesser	Challenging (Lack of literature would need to use an alternative method)
11	Review bundled mitigations	Feedback and validation are recommended on the mitigation bundle results with rural stakeholders. Including: - If bundles are appropriate for Auckland region - If the bundles include the mitigations AC wants (e.g. does M1=GMP)	4.3, 5.1, 5.2	High	Moderate (Re-configuration of options, limitation of output uses)	Ready
12	Refine mitigation bundles to exclude EOF mitigations	This would ensure that the possibility for double-counting costs and benefits of mitigation options is removed and the bundles and EOF mitigation options can be applied cumulatively with more confidence.	3.2	High	Lesser (Representing options)	Modest (Requires farm-system modelling)
13	Review TAC cost assumptions for rural sector	This applies an additional cost to any mitigations with a capital cost. The assumption of 17.5% aligns the rural and urban sectors but has not been validated for rural sector options.	3.2, 4.8	Low	Lesser	Ready
14	Changes in HRU groupings since the Baseline period	Determining changes to the extent of all HRU groupings (if not classes) over time and representing that change in the FWMT baseline modelling will help ensure "current state" as much as scenario outputs, are accurate.	4.1	Medium	Lesser	Challenging (Requires geospatial data and input layer generation)

Improvement area		Recommendation	Relevant report section	Initial prioritisation ranking		
				Importance	Complexity	Ability
15	Rotation crop consideration	Better understanding land use with long term rotations (e.g. both seasonal such as an arable and stock mixed system and across seasons such as potato crops) would help ensure if these are represented suitably in the FWMT or if adjustments need to be made. This would include considerations such as how potential changes in behavior may need to be captured, such as changing from lease arrangements to land ownership for long term horticulture rotations.	4.1, 5.1	Medium	Greater (Re-configuration of HRU)	Modest (Requires geospatial data, literature effects and costs)
16	Consider new mitigations (and/or modelling software) that include sediment and *E. coli* estimates	Most mitigation bundles lack sediment and *E. coli* estimates and in addition there are other mitigations focused on sediment and *E. coli* that could be considered however, the literature has tended to prioritise N and P, possibly due to modelling software, it is suggested this is explored further to improve estimates of current and new mitigation options on sediment and *E. coli.*	4.3, 5.1, 5.3	High	Lesser	Modest (Requires field trials, farm system modelling and literature)
17	Order of application of mitigations	This would investigate the relative mitigation costs and benefits when applied in different orders (e.g. EOF or bundled first).	4.4	Low	Lesser	Ready
18	Applicability of mitigations	Refine estimates of applicability of mitigations, especially the need for stock water reticulation and space planting of erosion controls trees.	4.5	Medium	Lesser	Modest (Requires survey data)
19	Adoption of mitigations	A strong recommendation is that the FWMT would be improved markedly for scenario and ongoing accounting exercises, through robust surveying of mitigation implementation on horticultural and pastoral land. Knowing the existing adoption of mitigations allows for a more robust estimate of costs and benefits predicated on more accurate understanding of the opportunity for each mitigation.	3.1, 3.2, 4.6	High	Lesser	Modest (Requires FEP programme to generate data on actions and additional survey data for mitigations beyond an FEP, made complex by the heterogeneity of mitigations adopted)

Improvement area		Recommendation	Relevant report section	Initial prioritisation ranking		
				Importance	**Complexity**	**Ability**
20	Consider inclusion (qualitative and/or quantitative) of costs and benefits not included in the FWMT Stage 1	This could include: - Tax, debt repayments and interest - Level of operating profit acceptable before insolvency - Variation in key prices (input/output) - Impact of mitigation on land values - Impact of mitigation on jobs and regional economic metrics (e.g. GDP) - Impact on regional and national food prices - Benefit of biodiversity, carbon sequestration and water quality improvements	4.7, 5.1, 5.2	High (Though this varies by each additional consideration)	Greater (Though this varies by each additional consideration)	Modest (Additional cost considerations could be included in modelling, proxies or regional modelling could test jobs and food prices, would be complex to include non-market benefits which requires a benefits framework to be developed)
21	Transition period	Better understanding how the costs, benefits and adoption rates across the 50-year time period would provide a more accurate picture of costs and benefits but would require significant information and assumptions. It would be complex and could increase uncertainty (the more assumptions that are made).	4.8, 5.2	Medium	Moderate (Requires new LCC modelling)	Challenging (Lack of literature)
22	Land use change	Including land use change options within the model, beyond the current scenario to native bush, which explicitly consider both capital and ongoing cost impacts will provide more flexibility to the scenarios modelled.	4.8	Medium	Moderate (Requires new mitigation option)	Modest (Requires new economic information)
23	Configuration of FWMT to explore alternative options for optimization/ allocation (e.g., natural capital; national regulation – NESFW)	Development of new scenarios to represent the effects of differing approaches to allocation, from simply cost-optimisation of all device or source control choices. Opportunities to represent natural capital-based optimization by optimizing for difference in contaminant loading under current land use and LUC-allocated land uses (requires considerable definition of HRU's to LUC). Opportunities to explore how the effects of national regulations deviate from or support cost-optimised strategies to achieving targets.	5.3	Medium	Greater (Requires HRU reconfiguration, new framework, new optimization rules)	Challenging (LRI available for reconfiguration but limited information or wider application to underpin modelling & significant assumptions required)

Improvement area		Recommendation	Relevant report section	Initial prioritisation ranking		
				Importance	Complexity	Ability
24	Consideration of collective mitigations	While the EOF mitigations can be considered across land parcels owned by a particular group or person from a benefit perspective, the cost framework is not configured in such a way that explicitly considers this option. It would require considering the collective cost of a mitigation(s) within a grouping of farms within an HRU.	5.3	Low	Moderate (Requires re-configuration of options)	Modest (Requires new costing evidence)

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