FRESHWATER MANAGEMENT TOOL – OUTCOMES AND LESSONS FROM TRADING COST FOR COMPLEXITY

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ABSTRACT

Auckland Council's Freshwater Management Tool (AC-FWMT) is a decision-support tool, to inform how to maintain or improve water quality in urban and rural streams.

The AC-FWMT is based on open-sourced, continuous and process-based US-EPA models (LSPC+SUSTAIN). LSPC+SUSTAIN approaches are also under development in Northland and Bay of Plenty. Though differing in scale, resolution and purpose the accounting frameworks provide decision-makers with integrated, objective-based[1] information on waterway health, including contaminant and flow regime (existing, future); causes (sources, process); costed actions to maintain or improve water quality (least cost, feasible).

The AC-FWMT simulates hydrologic and contaminant processes on-land and instream, for 15-min timesteps, from mountains to sea in an approach informed by the National Policy Statement for Freshwater Management 2020 (NPS-FM) (see prior StormwaterNZ abstracts – Stephens et al., 2020 & 2022).

Now, the AC-FWMT can produce Waterway Action and Investment Strategies (WAIS) – geospatial, cost and water quality information on feasible actions of least cost for water quality objective(s). WAIS provide cost distribution across intervention type, catchments, parties and lifecycle phases. WAIS are precursors to the water quality improvement plans that provide detailed catchment planning priorities on a sub-catchment basis but for integrated water quality objectives.

Our talk will reveal how minimizing implementation costs has required increasingly complex modeling in Auckland, creating challenges for appropriate extension, use and continuous improvement of modelling. Challenges come with risk and reward, in our instance providing new data, insights and evidence of how to manage water quality better.

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[1] *Objective* used in a regulatory/planning context of the NPS-FM, Resource Management Act 1991 (incl. ongoing revisions adopting NPS-FM). Examples include contaminant attribute states under the National Objective Framework that require improvement in numeric measures (concentration, load, flow) to within desired levels of some value (e.g., ecosystem health, human health).

WATERWAY ACTION AND INVESTMENT (WAIS) STRATEGIES – MULTIPLE, INTEGRATED OBJECTIVES CHALLENGE REGULATOR AND OPERATOR

The AC-FWMT is purposely designed around NPS-FM freshwater accounting requirements, including: numeric attribute-based decision-making for baseline and scenario conditions (Clause 3.7), provision of local chronic and acute sources of pressure (contaminant) on attributes for ecosystem and human health (Clause 3.29), integrated or cumulative effects on attribute state (Clause 3.5), and provision of action plans to avoid over-allocation (Clause 3.15). AC-FWMT WAIS report least cost mix types, scale and location of intervention to achieve water quality objectives, whether concentration or load-based.

The AC-FWMT records, aggregates and can report progress to objectives (e.g., dynamic stable-state changes in loads, concentrations, sources and amounts of contaminant managed by changes in practice and/or device).

In the AC-FWMT, WAIS span over x100 major rural and urban resource uses for variants of x111 intervention types (Auckland Council, 2021a-e). All actions are underpinned by feasibility modelling (biophysical and surface-type footprint, treated area), local sub-catchment effects (dynamic steady-state modelling) and lifecycle costs (direct acquisition, maintenance, renewal and purchase/opportunity).

The AC-FWMT value proposition is simple, better information and reduced costs to achieve generational changes in water quality. However, its objective-basis and dynamic-optimisation capability require assumptions that increase challenges for engagement and uptake on AC-FWMT outputs:

- Optimal solutions are specific to "assessment points" – water quality objectives must be set at representative locations whilst recognizing for interactions between land and water, and waterways to receiving environments (Clauses 3.11, 3.29). Modelling must trade more assessment points for lesser implementation efficiencies, but too few risks failing to achieve objectives throughout sufficient waterway.

(AC-FWMT assessment points are located furthest downstream prior to coast but include Tier 1 optimisation points in each sub-catchment prior to Tier 2 optimisation across sub-catchments at the assessment point).

- Optimal solutions target a critical condition – regulatory requirements are breached only during certain times. All nationally mandated objectives include numeric attributes or measures such as a 95^{th}% concentration, whose exceedance defines the critical period, sources and load needing management. WAIS are optimized explicitly only for the critical condition, increasingly sensitivity to baseline modelling.

(AC-FWMT critical conditions are numeric objective-based using the most conservative numeric attribute. For instance, either of 95^{th}% or median concentration in oxidized nitrogen whichever is graded more poorly – both chronic and acute degradation must be managed to achieve a water quality objective. Critical periods and amounts are combined into a critical load that is derived from land and network discharges to waterways. Baseline modelling is externally peer reviewed).

- Optimal solutions are chosen on broader (non-critical) conditions - alternative mixes of intervention are iteratively modelled for a short-period to initially identify x100 incrementally better but least cost, of ~250,000 possible combinations. Latter "Tier 1" optimisation curves are produced per sub-catchment but on a non-critical load. Each then permits ranking of x100's of best solutions across many sub-catchments to an assessment point (Tier 2 curve). Importantly, all optimal solutions then require assessment of what point on Tier 2 curves relate to sufficient management of critical conditions at assessment points.

(AC-FWMT utilizes May 2013 as the boundary condition for Tier 1, with May wettest month and associated with greatest contaminant loading to stream, and the water year 2013 being the closest of baseline water years to the long-term average annual rainfall depth).

- Optimal solutions must converge – sufficient intervention combinations must be modelled across Tier 1 conditions to offer confidence in finding least-cost incremental mixes. Critically, source controls (practice-based actions) exponentially increase the number of simulations required to achieve a converged Tier 1 curve.

(AC-FWMT convergence is larger [250k solutions per Tier 1 curve] than many US-EPA accounting exercises. Source controls are especially important on New Zealand rural activities so-called "good farming practices", but which increased computational demands considerably).

- Optimal solutions are sensitive to intervention information – Tier 1 curves vary between sub-catchments depending on opportunity (footprint available and upstream loads received), lifecycle costs and efficacy of possible interventions. Corresponding lifecycle and opportunity modelling thereby govern convergence, and catchment modelling.

(AC-FWMT is supported by extensive, transparent and reported lifecycle cost modelling, opportunity modelling and efficacy modelling consistent with statutory guidance in Auckland Council. Direct input of external stakeholders also underpins all ongoing intervention input decisions, with reporting already published or in preparation).

- Optimal solutions differ depending on prioritized objective – to select between exclusive actions, differing critical conditions must be prioritized (e.g., one contaminant targeted in preference to another). The alternative is to create optimized Tier 2 curves uniquely for each contaminant in all assessment points, with potentially differing critical conditions (e.g., times, sources, loads and therefore feasible related interventions). However, national regulation does not explicitly require a-prioritisation of attributes despite widespread understanding that potential interventions can overlap on footprint and be mutually exclusive – whether practice-based farming setups or urban devices.

(First generation AC-FWMT optimisation outputs target each of TSS, TN, TP, TCu, TZn and E.coli critical conditions, but in a unique specific order. Outputs will therefore differ if focused on fewer contaminants and/or in differing prioritized order. Selecting the order in which to prioritise attributes and to what degree of exceedance, is arguably the single greatest challenge to optimizing ahead of and informing rather than reacting to regulation).

- Optimal solutions require "cumulative" or routed assessment – impacts of upstream actions on downstream conditions are required by national water policy and reform (NPS-FM, 2020; Te Mana o te Wai – RMA, SPA, 3 Waters). Routed performance is a key requirement to avoid insufficient/excessive management of over-allocation (i.e., potentially over-managing if instream natural processes attenuate contaminant and/or on-land changes to hydrology reduce instream generation).

(Coupled LSPC+SUSTAIN optimisation pilots routed effects instream to determine the degree offset between critical loads from land and instream at assessment points).

Our talk will explore WAIS elements and learnings, before sharing the first-generation multi-contaminant, integrated WAIS for Auckland (see Figures 1-4).

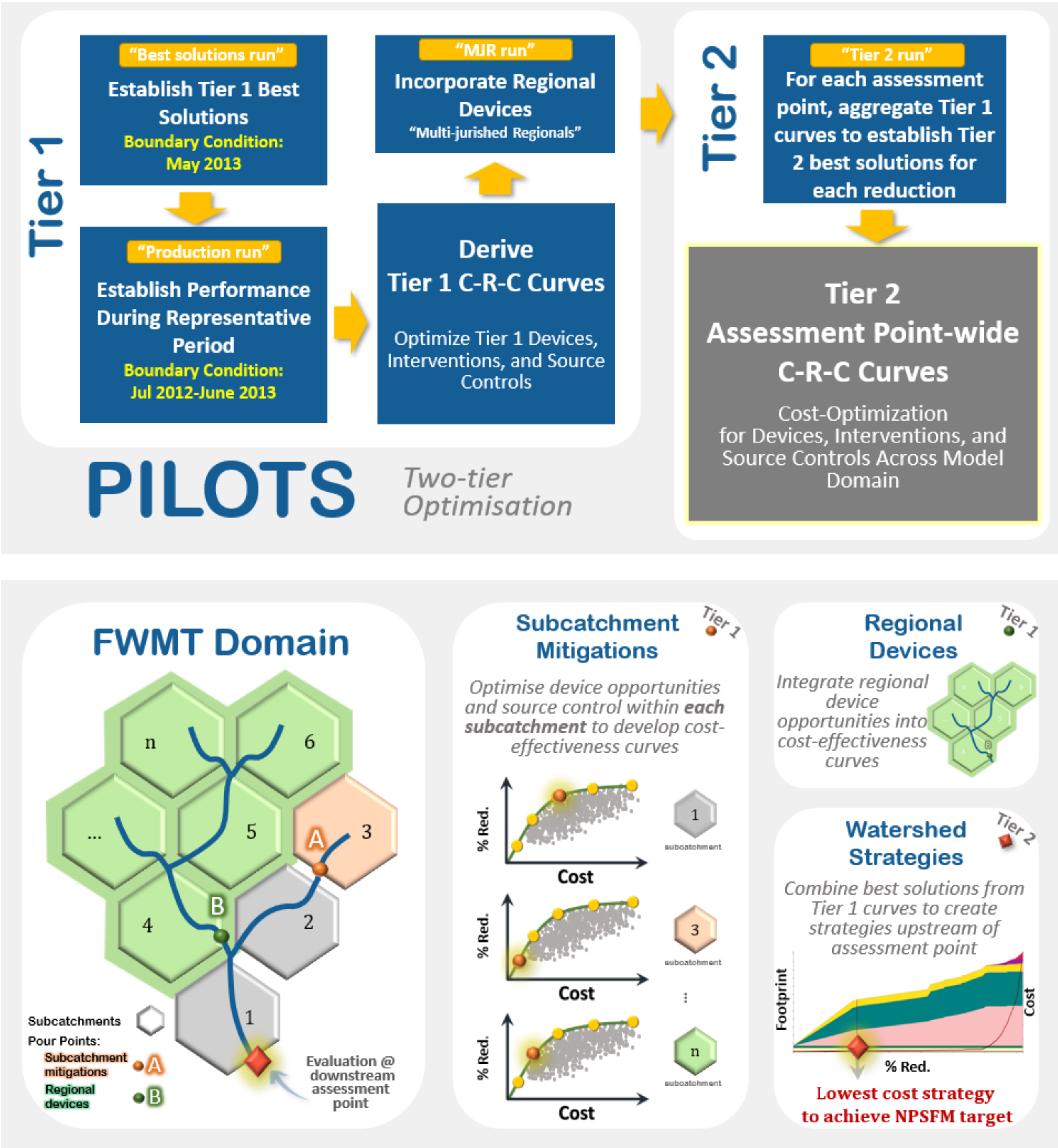

Figure 1. AC-FWMT - dynamic intervention, process-based and lifecycle-cost optimisation. Maximizing water quality benefit is conceptually simple but technically complex.

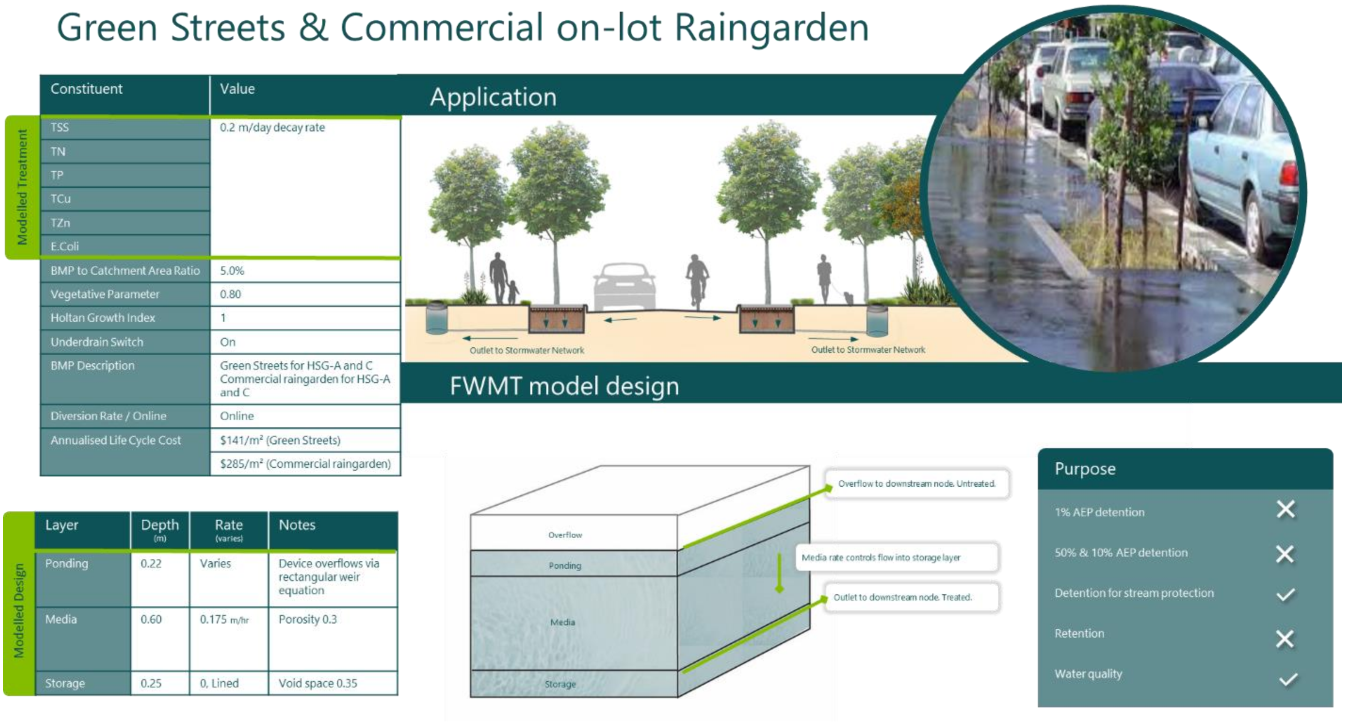

Figure 2. Example AC-FWMT intervention factsheet. Literature, field trials and targeted monitoring inform the process-representation of x111 intervention types in AC-FWMT.

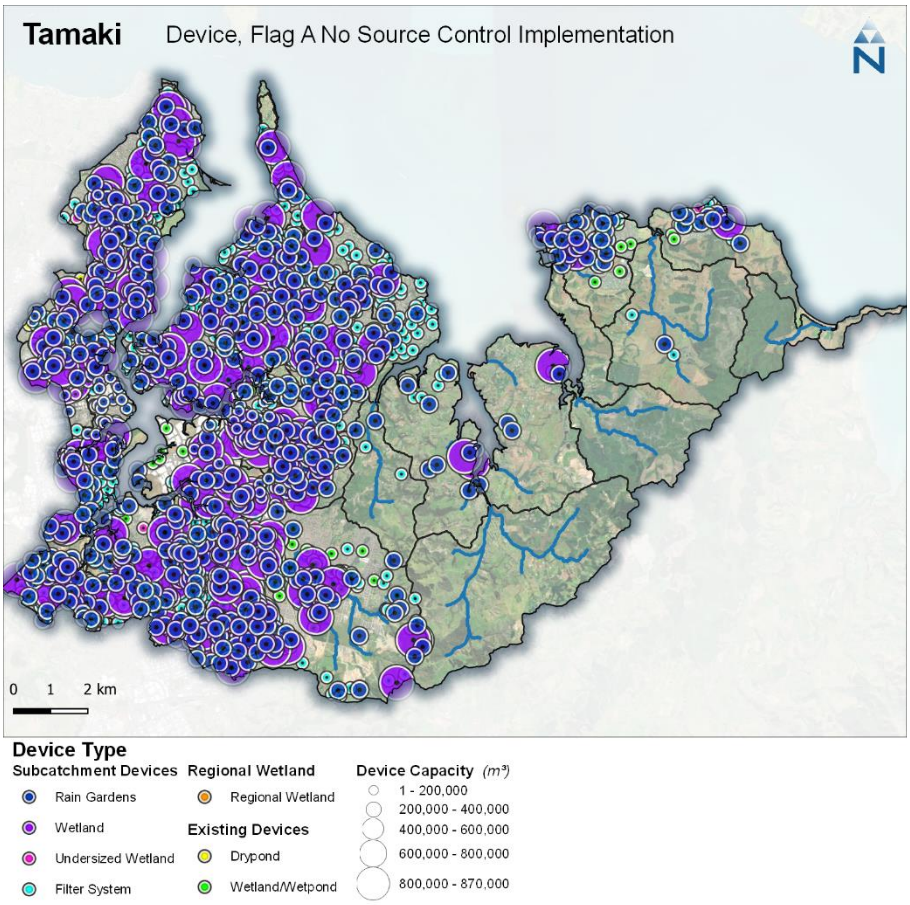

Figure 3. WAIS – optimal devices for A-grade Zinc (dissolved) for x19 assessment points (black outline) in Tāmaki watershed.

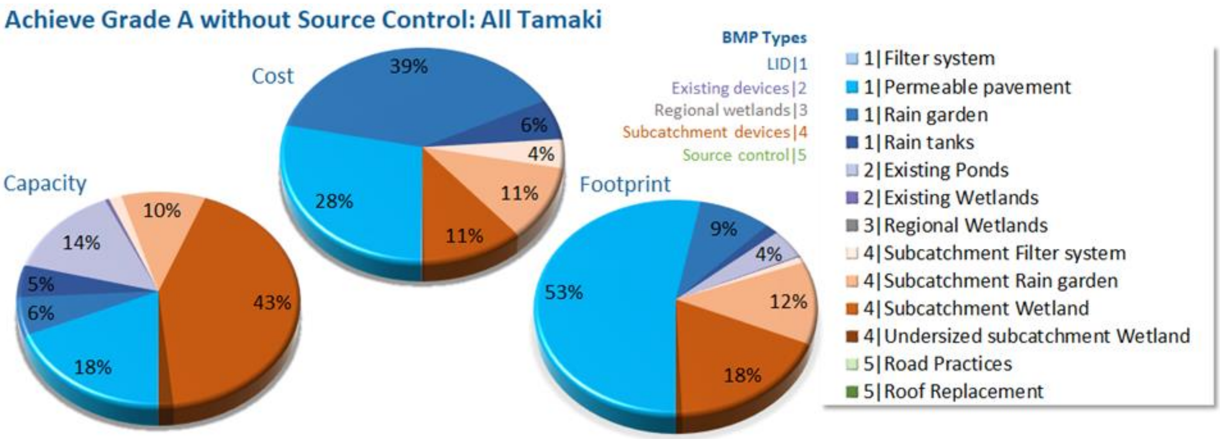

Figure 4. WAIS – optimal device investment for A-grade Zinc (dissolved) in Tāmaki watershed.

ARE OPTIMAL SOLUTIONS MORE CHALLENGING?

The AC-FWMT marks a radical advance in water quality decision-making for the Auckland region. Advances on earlier contaminant load modelling include model type (continuous, process-based, dynamic intervention, cost-optimizable), model coverage (5,465 integrated sub-catchments) and strategic capability (100+ activities, 100+ interventions, action-plans optimized for cost). Better information now exists regionwide on acute and chronic instream conditions, causes thereof, management opportunities for and least-cost strategies to maintain or improve water quality – so-called Waterway Action & Investment Strategies (WAIS).

WAIS can be generated for individual or combined contaminant objectives, regionwide in both rural and urban Auckland. WAIS report least-cost solutions for numeric objective(s) at assessment points, integrating across all upstream activities. WAIS provide geospatial information on targeted actions including intervention type, scale, location, effect and direct cost.

Whilst the AC-FWMT and other LSPC-SUSTAIN frameworks are increasing our capabilities to deliver ambitious water quality outcomes, their increased sophistication and demands on modelling capability, cost and data pose challenges to their broader adoption.

Our talk will stress a principle of "defensible simplicity", arguing the design of next generation accounting frameworks must judiciously add complexity where necessary and equally, simplifying. First generation AC-FWMT WAIS have been purposely simplified, by optimizing for:

- Concentration-based objectives – actions of optimal benefit to coastal or lake water quality (load-based objectives) can differ
- Instream contaminants – actions of optimal benefit are limited to those affecting nutrient, sediment, heavy metal and *E.coli* instream
- Prioritized critical load – actions of optimal benefit could differ if prioritized to a single contaminant instead of many
- Baseline state – actions are based on existing opportunities modified for development, but against a background of at least maintaining baseline condition
- Direct cost – indirect costs are important and additional, as are indirect benefits

KEYWORDS

Waterway Action and Investment Strategies (WAIS), Freshwater Management Tool (FWMT), Water quality, Management, Optimisation, Auckland