Scientific approach for Southland Estuaries

In accordance with the National Policy Statement for Freshwater Management & New Zealand Coastal Policy Statement

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Cover photo: N. Ward – Seagrass at Freshwater Estuary, Stewart Island.

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1. Executive summary

There is a current requirement to have a greater understanding of estuaries in Southland. The catalyst for this has been the National Policy Statement for Freshwater Management (NPS-FM). While it pertains to Freshwater it urges the coastal environment to be considered within the structure of integrated catchment resource management. Environment Southland has taken the stance that estuaries be considered within this framework, recognising their importance and significance to Southland. The estuary health programme (EHP) was developed to cater to this need by aiming to determine appropriate loads that will protect the current ecological state of these estuaries.

Components of the EHP have been reviewed to-date by multiple contributors. This has created some confusion and ambiguity around the EHP. The purpose of this document is to provide clarity around the EHP and to collate the review work done to date to achieve lucidity on the further development needed.

Overall, reviewers were in agreement that the ES State of Environment monitoring programme and proposed that EHP correctly identify and target the key issues affecting the Southland estuaries. Reviewers' comments have been collated and distilled by this document for clarity about future development of the programme. Many of the issues raised by reviewers were considered by ES to be either minor, irrelevant, or reflecting a limited understanding of the purpose of the Estuary Health Programme and/or the SOE monitoring programme.

The distillation of useful suggestions has been summarised at the end of the document. These include further consideration given to sediment and nutrient interactions, lag times of contaminants, a means to estimate past and contemporary loads, legacy effects of contaminants and further policy development.

2. Introduction

In 2014, Environment Southland determined that the Freshwater Management Units (FMUs), as prescribed in the National Policy Statement for Freshwater (NPSFM) 2014, included estuaries. The NPS-FM does not specifically require limits to be set for estuaries but does require them to be set for Freshwater Management Units. In Southland, this becomes highly relevant as most of the catchments in the region end in estuary bodies.

To bring in this concept of integrated catchment management, these environments should be considered with regard to load (The cumulative mass, weight, or volume of a constituent delivered to some location), rather than just concentration (primarily the approach taken by the National Objectives Framework (NOF) in the NPS-FM). Aggregated,upstream effects of river catchments influence the state of our estuarine systems; it therefore follows that a fully-integrated estuary-freshwater management approach should be applied.

To achieve this objective, the relationship between levels of catchment resource use and the ecological outcomes of Southland estuaries needs to be well defined. This is so that appropriate criteria can be developed to protect, maintain or improve their condition.

The ‘Estuary Health programme – (EHP; Fig 1.)’ has been developed to achieve this objective. The proposal for the first steps of this work, and the SoE monitoring data set which it relies on have been reviewed multiple times which has created a degree of confusion. This document aims to more clearly explain the Estuary programme which sits within the wider science programme (Fig. 1.); and to collate and clarify the review documents that exist. This will enable future efforts to focus on the most needed improvement and development.

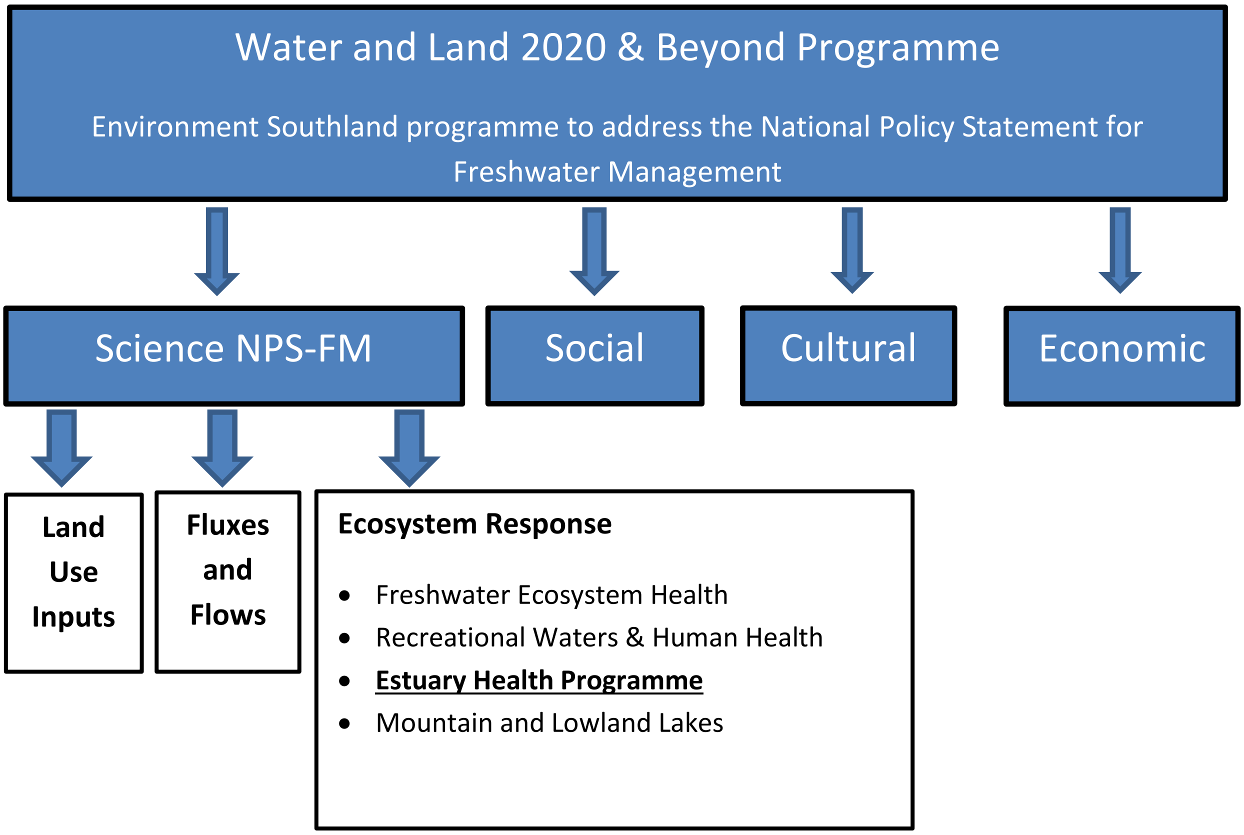

Figure 1. Diagram showing the wider structure of the NPS-FM Science programme.

3. Legislative Background

This section provides background to the legislation and policies which are relevant to resource management of estuaries in New Zealand.

2.1 National Policy Statement for Freshwater (NPS-FM) 2014

The NPS-FM 2014, requires regional councils to recognise the national significance of fresh water for all New Zealanders and Te Mana o te Wai (the mana of the water).

It directs regional councils to:

- safeguard fresh water's life supporting capacity, ecosystem processes, and indigenous species including their associated ecosystems;
- manage freshwater bodies so people's health is safeguarded when wading or boating (a minimum requirement);
- maintain or improve the quality of fresh water within a region;
- protect the significant values of wetlands and outstanding freshwater bodies;
- require more efficient use of fresh water by end users;
- avoid the over-allocation of water takes and inputs of contaminants;
- phase out existing over allocation.

It requires the implementation of a National Objectives Framework (NOF) by:

- setting freshwater objectives according to a specified process (i.e. the NOF) and tomeet community and tāngata whenua values, which include the compulsory values of ecosystem health and human health for recreation;
- using a specified set of water quality measures (attributes) to set the freshwater objectives (an objective can only be set below national bottom lines in specified circumstances);
- set limits which allow freshwater objectives to be met (e.g. a total catchment contaminant load or a total rate of water take);
- put in place measures to better account for water takes and sources of contaminants, and measure achievement towards meeting objectives;
- take a more integrated approach to managing fresh water and coastal water;
- fully-implement the NPS-FM by 2025.

In managing their water bodies regional councils must:

- establish freshwater areas (freshwater management units) across their regions (Fig. 2);
- identify the values (for example irrigation, mahinga kai, swimming etc.) that communities hold for the water in those areas;
- gather water quality and quantity information on the water bodies to assess their current state and decide the water quality objective or goal (grouped into A, B or C bands) for each value the community has chosen based on the economic, social, cultural and environmental impact to that community;
- the community is to assess how, and over what timeframes, those goals are to be met;
- maintain or improve water quality within their regions and cannot set an objective below a national bottom line;

Regional councils have discretion in meeting the above requirements according to their own biophysical, political and resource context.

Figure 2. Freshwater Management Units of Southland as of 2015 with the bottom of catchment associated estuaries.

2.2 NZ Coastal Policy Statement (NZCPS 2010)

The Resource Management Act 1991 requires a New Zealand Coastal Policy Statement (NZCPS) to guide local authorities in their management of the coastal environment. Local authorities must give effect to relevant provisions of the NZCPS in planning documents and resource consent authorities must have regard to relevant provisions when considering consent applications.

The purpose of the NZCPS is to promote the sustainable management of the natural and physical resources of the coastal environment, including coastal land, foreshore and seabed, and coastal waters from the high tide mark to the 12 nautical mile limit. It provides guidance to the Department of Conservation and local authorities.

The first NZCPS was issued in 1994. A new statement took effect on 3 December 2010 when the NZCPS 1994 was replaced.

The NZCPS contains 29 policies which are directed by 7 objectives. For the purpose of this document the major themes can be broken down into 7 aspects which best encompass the NZCPS. These are natural character and landscapes, historic heritage, coastal water quality, coastal hazards, harmful aquatic organisms and biosecurity, public use and biodiversity.

2.3 Regional Policy Statement (RPS 2015)

A Regional Policy Statement (RPS) is a high-level mandatory document that sets out resource management directions for a region. It contains an overview of the significant resource management issues facing a community, including issues of significance to tāngata whenua, and outlines direct actions required to address these issues including measures to indicate whether objectives have been achieved. RPS's also show how a region will achieve integrated management of natural and physical resources through regional and district plans.

As regional and district plans are directed by a RPS they sit below the RPS in the hierarchy of planning documents. A RPS has two main roles:

I. To address regionally significant issues in an integrated way; and,
II. To allocate responsibilities to regional, district and city councils.

Regional and district plans must 'give effect' to polices within a RPS. Therefore the contents of an RPS will directly influence what councils do including through helping prioritise the delivery of services through the Long Term Plan (LTP) and annual plan processes.

The NPS-FM is a critical document that Council must implement through the RPS and regional plans. The NPS-FM requires, as a bottom line, the maintenance of overall water quality. In reflection of this Environment Southland has made a firm decision through the RPS to maintain all water quality in Southland. The Council does not want water quality to degrade any further than the current position within the various catchments of the region. Maintaining water quality in all water bodies is consistent with Objective 1 of the NZCPS which requires estuarine and coastal water quality to be maintained.

2.4 Ngāi Tahu ki Murihiku Natural Resource and Environmental Iwi Management Plan

The regional and territorial authorities have an important relationship with Murihiku tāngata whenua, based on a charter of understanding, which is endorsed by the Rūnanga o Ngāi Tahu. Importantly, this charter recognises a co-management model. The plan provides a guide for greater understanding of tāngata whenua values and issues identified by Ngāi Tahu ki Murihiku.

The Iwi Management plan is divided into sections, and includes section *3.6 Southland's Coastal Environment, Te Akau tai Tonga*.

Te Mimi o Tu Te Rakiwhanoa (Fiordland Coastal Marine Area) and Rakiura/Te Ara a Kiwi (Stewart Island/Foveaux Strait Coastal Marine Area) represent areas of historical and cultural identity for Ngāi Tahu. The importance of these areas is recognised in the Ngāi Tahu claims settlement Act (1998) as Statutory Acknowledgments recording the relationship between Ngāi Tahu and the southern coast and seas. Ngāi Tahu ki Murihiku promote consultation for any activities that may be undertaken within, adjacent to or may impact on Te Mimi o Tu Te Rakiwhanoa and Rakiura/Te Ara a Kiwi.

New Zealand Biodiversity Strategy

Coastal and Marine Biodiversity

- **Desired outcome for 2020**
  "natural marine habitats and ecosystems are maintained in a healthy functioning state. Degraded marine habitats are improving. A full range of marine habitats and ecosystems representative of New Zealand's indigenous marine biodiversity is protected "

- **Objectives**

- Substantially increase our knowledge of coastal and marine ecosystems and the effects of human activities on them

- Protect biodiversity in coastal waters from the adverse effects of human activities on land in the coastal zone

- Protect biodiversity in coastal and marine waters from the adverse effects of fishing and other coastal and marine resource uses

- Protect a full range of natural marine habitats and ecosystems to effectively conserve marine biodiversity, using a range of appropriate mechanisms, including legal protection

- Protect and enhance populations of marine and coastal species threatened with extinction, and prevent additional species and ecological communities from becoming threatened

2.5 NZ Biodiversity Strategy

'The term 'biodiversity' is commonly used to describe the number and variability of living organisms. This very broad usage, embraces many different parameters and is essentially a synonym of 'Life on Earth'. It has become a widespread practice to define biodiversity in terms of genes, species and ecosystems, corresponding to three fundamental and hierarchically-related levels of biological organisation.' (The United Nations Environment Programme's World Conservation Monitoring Centre 2013, UNEP-WCMC).

Managing for biodiversity is important because ecosystems that are more diverse have greater resilience. They are more likely to be stable and have a greater chance of adapting to environmental changes. Biodiversity also plays an important role in providing food, building materials, breaking down waste, helping erosion control, moderating climate, recycling nutrients, performing pest control and building soils. These 'ecosystem services' enable our agricultural, horticultural and tourism-based economy in Southland. So it is essential to preserve biodiversity for the sake of human wellbeing. Once biodiversity is lost it is largely irreversible.

A National Biodiversity Strategy was developed for New Zealand in 2000 to, in part, fulfil commitments made under the Convention on Biological Diversity [1]. The New Zealand Biodiversity Strategy (NZBS)

[1] The Convention on Biological Diversity (CBD) is an international legally binding treaty that was opened for signature at the Earth Summit in Rio de Janeiro (1992) and entered into force in 1993. The CBD has three main goals: i) conservation of biological diversity (or biodiversity); ii) sustainable use of its components; and iii) fair and equitable sharing of benefits arising from genetic resources.

establishes national goals and actions to “turn the tide on the decline of our biodiversity and to maintain and restore a full range of our remaining natural habitats and ecosystems and viable populations of all native species”.

NZBS describes a desired outcome and action plan to realise the goals of the NZBS. The action plan consists of objectives and steps designed to target gaps and inadequacies in the existing approach so that desired goals are achieved.

2.6 Estuaries in Southland

Estuaries have been, and continue to be, integral to the lifestyles of New Zealanders, especially in Southland, where many of our catchments end in iconic estuaries some RAMSAR sites), including two of international significance.

Ngāi Tahu Papatipu Rūnanga ki Murihiku hold water in the highest esteem because the welfare of the life that it contains determines the welfare of people reliant on that resource.

Although our coastal waters are perceived to be generally of high quality by international standards, some estuarine areas are under severe stress through land reclamation, encroachment from land development, contaminated runoff, excessive sedimentation and damage from other human activities. In Southland, the loss of habitat and ecological degradation observed in the upper arms of the New River and Jacobs River Estuaries are amongst the worst in the country (B Robertson, M Townsend, D Lohrer pers comms 2015). There is a concern that once the estuarine ecosystem buffering capacity (assimilation of nutrients) is exceeded, coastal water quality issues will become much more prevalent.

However, NPS-FM does not, specifically, require limits to be set for estuaries but does require integrated management to minimise adverse effects to the coastal water. In Southland, the approach has been decided to form freshwater management units which include associated estuaries with the catchment. For example, Oreti and Waihopai catchments will be included into one freshwater management unit with New River Estuary. For the places that are under the ‘coastal marine area (CMA)’ the New Zealand Coastal Policy Statement will apply. Regard must be given to estuaries for the management of freshwater, as they are hugely influenced by freshwater management and likely to be more sensitive to pollutant loads. The cumulative upstream effects of river catchments influence the life-supporting capacity of our estuarine systems and waters of our seaward coastal environment. It therefore follows that a fully integrated estuary-freshwater management approach be applied.

This approach requires information about the relationship between catchment resource use and the ecological effects on, or the associated 'condition' of, Southland's estuaries (see below) so that appropriate criteria can be developed to protect, maintain or improve their condition.

In order to provide such information the following work is being undertaken.

4. Estuary Health Programme Project Details

3.1 ES Science Programme

A description of the wider Science programme can be found in Appendix 1.

3.2 Project Overview

The project goal is to produce a '**tool'** which enables the community to appreciate the ecological condition of the receiving environment according to the corresponding load (The cumulative mass, weight, or volume of a constituent delivered to some location). The tool will utilise knowledge about catchment load and resultant ecological health. Currently, the approach being taken by the council is to build some "science capital", prior to consulting the community regarding values and limit setting. Therefore, at this time, community values are unknown. However, understanding the ecological outcomes is considered a fundamental building block when it comes to understanding community value outcomes.

Additionally, consideration will be given to compounding factors such as: loss of estuary volume and habitat (e.g. via reclamation); contaminant fate; links between sources and sinks; and other drivers of ecological state beyond loads.

Limit setting for the purpose of resource management requires the council to describe relationships between estuary condition and the main ecological stressors. These stressors are primarily catchment contaminant inputs of nutrients and sediments; with secondary influences including changes to estuary hydrodynamics from estuary reclamation and infilling, alterations to marginal habitats (e.g. saltmarsh clearance, drainage, flood controls, water abstraction) and over-harvesting of species.

In order to build this 'tool' several steps have been developed:

1. Formulation of 'Ecological Condition Gradient'

- This is the collation information from multiple estuaries onto a single scale considering, state and load from different comparable examples and for the given water body through time. It will encompass all the following work.

2. Drivers of Estuaries

- Collate and consider the current state of knowledge around estuaries in southland.

3. Determination of Estuary State

- This will be based upon scientific measures such as macroalgae cover, seagrass loss, oxygenation of sediment, nutrient concentration in sediment, which have been acquired over time. This is consistent with international approaches to determine estuary state; and will include some existing information from State of Environment monitoring to do this.

4. Characterisation of Estuary Morphometrics

- This is the characterisation of physical properties of the estuary which regulates the loads retained by the estuary i.e. the realised load. This is important as one estuary's load may differ to another due to the physical properties. This step will allow inter-estuary comparison.

5. Hydrodynamics

- Utilising models to further elucidate variation in water flows, velocities and levels and therefore fate of contaminants in the estuary. This will give a calculation as to the retained load in different estuaries.

6. Source Tracking

- Understanding the source of contaminants will be fundamental to limit setting as this information will become essential for mitigation purposes. The hydrodynamics will provide more insight to this work, defining what happens to contaminants within the estuary and therefore sources.

7. Determination of Estuary Loads

- This will estimate the loads of contaminants to an estuary through time from differing land uses. Initially the work will be based on annual loads but will also take into consideration seasonal loads and large events and how this may influence retained load.

Ideally, this would be done on a catchment/estuary-specific basis, however, estuaries can be grouped into broad types to set overarching management criteria that can then be tailored to meet specific needs. NZ has 4 basic estuary types: tidal lagoons (e.g. New River Estuary), tidal rivers (e.g. Piako Estuary, Waimatuku), coastal embayments (e.g. Wellington, Bluff Harbour) and fiords (e.g. Milford Sound). Some tidal lagoon and tidal river estuaries have mouths that intermittently close and open (e.g. Waituna Lagoon). The susceptibility of these estuaries to stressors varies depending primarily on the extent of:

- retention of the primary stressors (i.e. nutrients and fine sediment, and to a lesser extent toxins and disease causing organisms) i.e. flushing potential
- habitat loss through such actions as reclamation and artificially opening/closing lagoon mouths, and
- harvesting of estuary resources.

Tidal lagoon estuaries, because of their combined high biodiversity, and tendency to retain nutrients and fine sediments, are particularly vulnerable to increased catchment and point source loads. Within Southland, tidal lagoon estuaries dominate within the developed catchments and it is these estuaries where monitoring results indicate degradation has occurred, and therefore the project will focus on these.

In scientific terms, the ecological condition of such estuaries is determined using relevant ecological response indicators (or attributes) e.g. extent of seagrass beds, presence of nuisance macroalgae, extent of soft mud. Various approaches are then used to link the response indicators back to relevant load limits and other co-factors and management controls (e.g. hydrology). A key step in identifying the response of ecological indicators is to identify:

- a gradient of change from “natural state” through to its “current state”, the ecological gradient will be made up from relevant estuary attributes (indicators) and thresholds will be developed for each from existing estuary data.
- the state of the estuary if only the NPS freshwater “bottom line” thresholds for freshwater quality were met.

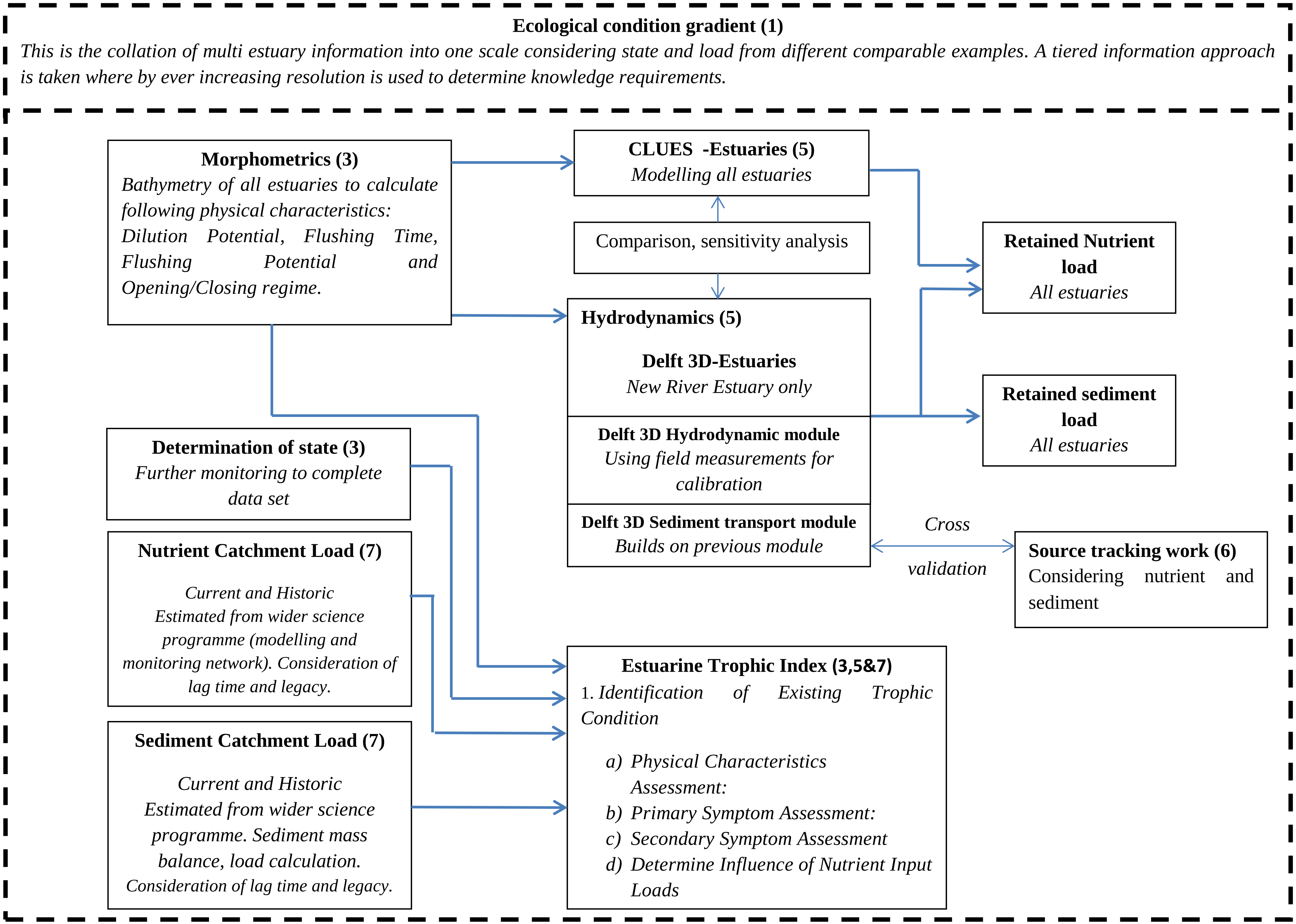

Figure 3. Diagram of the project structure, numbers correspond to previous text.

Table 1. Status of current programme as of January 2016.

Work Stream			Status	Comments
Estuary Health Programme	**Determination of State**		To be completed summer 2015_16.	Information will be sourced from a variety of locations and historic data to develop the ECG.
	Characterisation of Morphometrics		Bathymetry data completed for all of Southland. • DEM complete for NRE, • all other estuaries to be converted into DEM -Mar 2016.	Feeds into CLUES estuaries and ETI to provide more resolute calculation of: *Dilution Potential, Flushing Time, Flushing Potential and Opening/Closing regime.*
	Hydrodynamics	**Delft 3D**	Due for completion: • Calibration - Jan 2016 • Sediment particle transport module – Feb 2016 • Final report and model – Mar 2016	Once complete will provide information on source tracking and sediment fate. Sensitivity analysis to be done for CLUES-Estuaries vs. Delft 3D.
	Source tracking	**Sediment**	Consider lag time and legacy, substrate mapping, cores for historic sedimentation rates. Currently in development	In development
		Nutrient	Consideration around Macroalgae nutrient source tracking and sediment nutrient dynamics is currently in development with Otago University.	In development
	Determination of loads	**Sediment**	As part of wider Science programme – being considered in sediment project (Soils & Freshwater Team Leader – Project Leader).	Needs consideration around current and historic loads.
		Nutrient	As part of wider Science programme – being considered in Fluxes and Flows (Environmental Scientist– Project Leader).	In development
	Ecological Condition gradient		Contracted to begin Sep 2016, to be completed by Jan 2017.	Contracted to Wriggle Coastal Management Ltd

Support Work	**Estuarine Trophic Index**	The ETI Toolbox, currently being developed under Envirolink funding by Wriggle Coastal Management and NIWA for the Regional Council Coastal Special Interest Group. It will be available early 2016.	
	CLUEs Estuaries	Status report due. Currently in development for NRE using same DEM used in Delft 3D model. Minor modifications to the CLUES-estuary code will be made shortly to improve functionality.	The modifications will allow the user to over-ride input parameters to CLUES-estuary (such as inflow, tidal prism, volume, and riverine nutrient concentration) which will greater flexibility for scenario testing, but also provide a 'work-around' for addressing seasonality.
	PhD Research	Ben Roberston (BSc. Hons and Otago University PhD candidate) is undertaking research aimed at developing relevant eutrophication state indicators and thresholds for shallow, intertidally dominated, estuaries (i.e. New Zealand's dominant estuary type).	The research will provide a type-specific continuum of estuary condition, including accurate trophic and sedimentation condition classification, and a strong framework for setting and achieving national management objectives (e.g. the NZ Estuarine Trophic Index Tool).

3.3 Project Details

The diagram below (Fig. 3) gives conceptual idea of how the various project components fit together along with the outputs (& Table 1). It is worth noting that the overarching framework of this work is the ecological condition gradient which derives the information needs with a view to achieving the project goals. These are two different approaches to tackling this problem both with limitations, currently it is proposed that both avenues are pursued multiple lines of evidence.

1. Formulation of 'Ecological Condition Gradient'

This is the collation of multi estuary information onto one scale considering state and load from different comparable examples and for the given water body through time. The approach would combine the information in the above points and Figures 4 and 5 to produce a tool which would look like Figure 6. This can then be further translated into a multi stressor view which considers the sediment and nutrient drivers (Fig. 7) A tiered information approach is being taken whereby ever increasing resolution will provide the needed knowledge level.

SOE monitoring of Southland shallow, intertidal dominated tidal lagoon estuaries has identified a gradient of nutrient and sediment associated impacts, including an increasing presence in some estuaries of eutrophic habitat, muddy sediments, and associated ecological changes - especially in upper estuary areas. This extensive, peer-reviewed dataset (plus supporting data from estuaries outside the region) will form the base foundation of the data analysis for this estuary type.

The key elements to the work are as follows:

- Undertake data analysis, and identify load/ecological response relationships.
- Establish habitats of interest (susceptible habitats) and species of interest.
- Establish an initial context for condition and matching contaminant loads using this data on Southland estuaries e.g. New River, Jacobs River, Waikawa, Haldane, Freshwater, as well as estuaries with a more extensive range of load responses. A GIS based approach will be used as appropriate to process and present existing data.

Where possible, example estuaries for shallow tidal lagoons will be selected based on their expression across a range of fine sediment and nutrient impacts in establishing the context. Symptoms of such impacts will be determined using available estuary data (in particular relevant research publications and the extensive broad and fine scale monitoring data collected by Regional Councils around NZ). Appropriate indicators for each of the selected symptoms will then be identified using proven indicator/response relationships, supported in some cases by expert opinion where validation of empirical relationships requires further effort, and broad and fine scale indicators measured throughout each example estuary.

Broad and fine scale indicators will be assessed from two main selected habitats; firstly, the most at-risk habitats (e.g. sediment deposition accumulation zones in upper estuary areas - determined from available monitoring data or sediment deposition models) and, secondly, the dominant remaining habitat (e.g. un-vegetated intertidal flats in main basin of tidal lagoons).

The main focus will be on primary producers e.g. seagrass, saltmarsh, phytoplankton and macroalgae, (and associated habitat quality elements) as the main indicators given their foundation role in the estuary food-web, but will be supported by associated secondary producers (e.g. community benthic macroinvertebrate structure information where available). Thresholds for higher trophic levels (e.g. fish and birds) will not be directly developed in this component of the decision support tool (due to lack of available monitoring information). Instead, a preliminary assumption is made that the foundation indicators of the estuary habitat/food web are also a reasonable indicator of higher trophic level condition (i.e. the ecological condition indicators or attributes that drive the fishery in response to nutrient and sediment loads are mainly those foundation level primary and secondary indicators outlined above).

This work will be facilitated by incorporating GIS layers of relevant data (existing layers as well as layers generated using standard model builder outputs within ARCMap). Such data will be collated and presented in a format intended for easy use with existing spatial analysis tools and to facilitate clear communication to stakeholders.

3.4 Supporting Work

The above approach for limit setting for ES FMU estuaries is supported by the following associated work streams:

Estuarine Trophic Index (ETI) Toolbox.

The ETI Toolbox, currently being developed under Envirolink funding by Wriggle Coastal Management and NIWA for the Regional Council Coastal Special Interest Group, will complement and support the tools described in this plan by providing:

- guidance on how to type an estuary,

- a rating system for physical susceptibility to eutrophication,
- a list of recommended indicators with guidelines for monitoring,
- software for deriving an estuary ETI score from values of indicators.

This information will support, in particular, scenario testing and back-calculation of nutrient load limits.

The intent of the tool is to accurately evaluate eutrophic conditions of NZ estuaries and to identify appropriate input loads for the key stressor, nitrogen. The approach needs to characterise the level of ecological impairment, and the dominant source(s) and level of pollutant that has caused observed impairment, so that management measures can be targeted for maximum effectiveness. This is achieved by the following steps.

1. Identification of Existing Trophic Condition (e.g. expression of eutrophic symptoms; low, moderate, high). Via:

(a) Physical Characteristics Assessment:

Involves determining a number of physical indices to determine the physical susceptibility of the estuary. These indices can include the following:

- Dilution Potential: calculated as 1 ÷ estuary volume (m^3))
- Flushing Time (days) (equals the mean time that water spends in an estuary). Flushing Time = (HW Volume x tidal period)/Tidal Prism).
- Flushing Potential: calculated as freshwater inflow ($m^3.d^{-1}$) divided by estuary volume (m3) and adjusted for tidal height (m).
- Opening/Closing regime.

These are then combined, to produce a likely potential for export of nutrients from the estuary and therefore determine its physical susceptibility.

(b) Primary Symptom Assessment:

An assessment of existing symptom monitoring information for primary symptoms of eutrophication (i.e. nuisance plant growth - macroalgae, phytoplankton and epiphytes). These are scored and used to develop a primary symptom rating.

(c) Secondary Symptom Assessment

An assessment of existing symptom monitoring information for secondary symptoms of eutrophication (e.g. sediment indices TOC, TN, RPD to account for the fact that shallow NZ estuaries have predominantly sediment related impacts rather than water column impacts). These are scored and used to develop a secondary symptom rating.

(d) Determine Influence of Nutrient Input Loads

Assessment of N load on the estuary in relation to the resultant concentration after retention and dilution. Note this produces a rating for the overall N Loading Influence, but not an indication of what the appropriate N load is to ensure no eutrophic symptoms.

The final step is to combine these various ratings to give a final expression of eutrophic status rating – Low to High

2. Identification of input load eutrophic response bands

Appropriate stressor (N Load) bands based on existing trophic response data (i.e. monitoring data of key eutrophication symptoms - TOC, macroinvertebrates, macroalgae, phytoplankton, sediment TN, sediment TP, RPD, water column nutrients, seagrass area, saltmarsh area) are used.

Estuary Condition Gradient PhD Research.

Ben Roberston (BSc. Hons and Otago University PhD candidate) is undertaking research aimed at developing relevant eutrophication state indicators and thresholds for shallow, intertidally dominated, estuaries (i.e. New Zealand's dominant estuary type). The research, being mentored by Wriggle and University of Otago scientists and supported by Regional Council, University Scholarship and Wriggle funding, will provide a type-specific continuum of estuary condition, including accurate trophic and sedimentation condition classification, and a strong framework for setting and achieving national management objectives (e.g. the NZ Estuarine Trophic Index Tool).

CLUES estuaries

The CLUES estuaries tool can be applied for both evaluating the impact of land-use change on estuary nutrient concentrations and as a regional or national screening tool.

Currently a validation exercise is underway comparing CLUES-estuary predictions of nitrogen concentrations with data from a range of estuaries (Bruce Dudley).

Minor modifications to the CLUES-estuary code will be made shortly to improve functionality. It is hoped that these can be rolled out with the next version of CLUES.

Seasonal inputs – the estuary component of CLUES-estuary is ready to accept seasonal inputs, but there is still some work required to obtain these from CLUES, and to link the CLUES/CLUES-estuary tools to accept these inputs. The code modifications described above will allow the user to over-ride input parameters to CLUES-estuary (such as inflow, tidal prism, volume, and riverine nutrient concentration) which will provide greater flexibility for scenario testing, but also provide a 'work-around' for addressing seasonality.

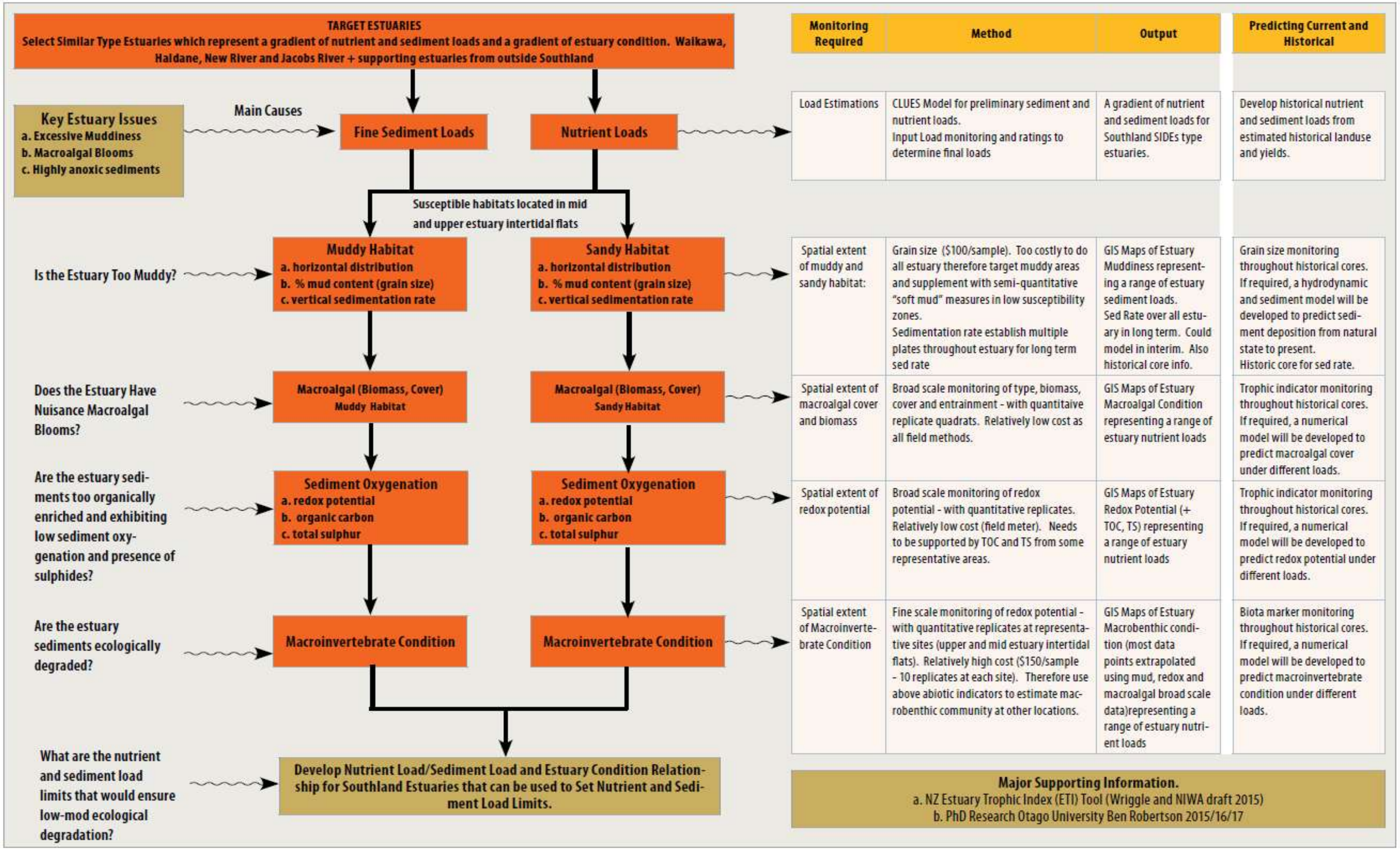

Figure 6. Southland Shallow, Intertidal Dominated Estuaries (SIDEs). Proposed ECG approach to nutrient and sediment load limit setting.

Fine Sediment Load Impacts	Nutrient Load Impacts				
	Very Low	Low	Moderate	High	Very High
Very Low		Freshwater			
Low	Westhaven, Bluff Awarua	Puponga	Toetoes		
Mod.		Haldane	Motupipi	Waikouaiti	Avon Heathcote 2002
High		Waikawa	Porirua, New River 2002	New River 2010	New River 2015, Jacobs River
Very High		Havelock, Waimea	Moutere		

Figure 7. Combination matrix for two contaminants gives total of 25 possible combinations for each estuary type ECG.

2. Drivers of Estuaries

This work was initially to consider the current state of knowledge around estuaries in southland. However the scope of the work was altered to provide reviews of the estuary data and the proposed ecological condition gradient (ECG). The reviews are further considered in the 'Review' section below.

3. Determination of Estuary State

It is proposed that the condition of the estuary be described along a gradient from "pristine" to "highly degraded" that has been defined *a priori* (the "Ecological Condition Gradient" (ECG)) (Fig. 4). Information will be sourced from a variety of locations to develop the ECG including; monitoring data from the target estuary (particularly changes over time under different catchment land uses and intensities), data from other NZ and overseas estuaries of a similar type (covering a range of examples from "pristine" to "bad"), historical sediment cores (documenting changes in catchment land cover, sedimentation rates, shellfish, etc.), and relevant historical information (e.g. aerial photos, records of estuary reclamations, changes in depth or clarity, algal blooms, fisheries values, extent of mud, etc.) (see Final Section for details).

The main focus will be on primary producers e.g. seagrass, saltmarsh, phytoplankton and macroalgae (and associated habitat quality elements), as the main indicators given their foundation role in the estuary food-web, but will be supported by associated secondary producers (e.g. community macroinvertebrate structure information where available, up to the benthic macroinvertebrate level). Thresholds for higher trophic levels (e.g. fish and birds) will not be directly developed in this component of the decision support tool (due to lack of available monitoring information). Instead, a preliminary assumption is made that the foundation indicators of the estuary habitat/food web are also a reasonable indicator of higher trophic level condition (i.e. the ecological condition indicators or attributes that drive the fishery in response to nutrient and sediment loads are mainly those foundation level primary and secondary indicators outlined above).

It is proposed that this be a weight-of-evidence approach that integrates multiple indicators to provide a robust overall indication of estuary state (i.e. the use of both primary and secondary, or supporting, indicators). For example, a diverse and abundant macroinvertebrate community may include relationships between absence of nuisance macroalgal growth, oxygenated sediments, healthy seagrass beds, and low mud, sulphide, and nutrient contents.

The approach includes the response to nutrient and sediment loads of physical and chemical characteristics, primary producers and macroinvertebrates, i.e. not just primary producers. These indicators have been selected as appropriate for the estuary type in question (i.e. shallow, very short residence time, high intertidal area, tidal lagoon estuaries). For such estuaries, the estuary sediment, not the water column is the most vulnerable; and the most vulnerable area in the estuary is the upper estuary flocculation zone. The approach chosen focuses on the most vulnerable areas and as such it provides a relatively good indication of overall ecological state, this will not create a biased approach as the mudflats of an estuary are fundamentally necessary for the overall health of an estuary.

It is important to keep in mind the objective is to understand the response of physical, chemical and lower trophic levels (i.e. primary producers and macroinvertebrates) to nutrient and sediment loads. Other stressors are likely to influence shellfish or fish populations (e.g. human harvesting), however this is a separate issue to contaminant limits and therefore will be raised in this component of the decision support tool as examples of potential modifiers.

Observations of condition can be obtained from monitoring data. ES has some of the best monitored estuaries in NZ, and condition monitoring data for the last 10 years has documented large changes in condition that correlate with modelled changes in contaminant loads associated with catchment land use intensification and change. This data includes strong associations between the key stressors and biological changes.

The relationship between loads and ecological condition can be provided by a “space for time” replacement – that is finding data from equivalent/similar estuaries (national and international), but whose conditions are at a different position on the ECG, and where the loading rates are known and where flushing characteristics are the same. This work has already been done to some extent, but additional data will need to be collected from relevant locations in other estuaries. This provides information both on ecological condition and loading rate across most of the ECG.

It is important to realise that this first step in the process will highlight and identify the limits necessary to maintain ecological health.

The possibility of collecting additional data will be explored through the following:

- Aerial photography and remote sensing
  Historic and current data can be used to determine change of important habitat through time and then relate by time to the ecological state/load this relates to.
- Repeat historic studies
  Some key studies will help further detail information e.g. sedimentation studies undertaken in the 1980s could be repeated to better determine changes in substrate over time, a key driver of ecological state.

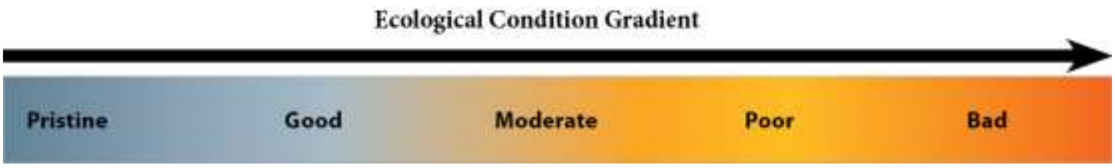

Figure 4. Visual representation of the Ecological Condition Gradient (ECG) concept.

4. Characterisation of Estuary Morphometrics

The aim of this work stream is to determine the retained loads of estuaries based upon various morphometric measures such as the basin shape, topography and bathymetry.

Because the targeted Freshwater Management Units (FMU) estuaries fall into three main physical types with respect to their ecological response to nutrient/sediment loads, an ECG will be generated for each type, as follows:

1. Shallow, intertidally dominated tidal lagoons (includes Waikawa, Haldane, New River, Jacobs River, Toetoes Harbour)
2. Shallow, intertidally dominated tidal rivers (includes Waimatuku)
3. Shallow Intermittently Closed and Open Lakes and Lagoons (ICOLLs; including Waituna, Lake Brunton, Waiau, and the coastal shallow lakes, the Reservoir and Lake Vincent).

This amalgamation into types and standardisation via morphometrics will allow inter-estuary comparison within estuary types and therefore for estuaries to be populated on the ‘ecological condition gradient’. The flushing capacity of an estuary needs to be sufficiently understood to appreciate the links between pressure and response, and to apply relationships derived from one system to other systems. Additionally even working with just one system, it might be the case that flushing capacity changes, for instance as tidal prism reduces because of sedimentation or maybe the opening-closing regime changes for some reason, in which case the relationship between input loads and the retained load will also change. Ideally a hydrodynamic model will be formed for each estuary, but this is likely to be unachievable for smaller catchments as the larger catchments will be prioritised for hydrodynamic models.

The specific information to derive the physical indices that determine the physical susceptibility of the estuary will be:

- Dilution Potential: calculated as 1 ÷ estuary volume (m^3)
- Flushing Time (days) (equals the mean time that water spends in an estuary). Flushing Time = (HW Volume x tidal period)/Tidal Prism).
- Flushing Potential: calculated as freshwater inflow ($m^3.d^{-1}$) divided by estuary volume (m3) and adjusted for tidal height (m).
- Opening/Closing regime.

5. Hydrodynamics

This work stream aims to determine changes to physiographic character (e.g. basin shape, topography, bathymetry) which in turn will alter hydrodynamic function leading to variation in water flows, velocities and levels. This has further implications to sediment transport and changes to erosional/depositional/accreting character and therefore habitat stability. Consequently this can cause hydrographic alteration causing changes in food supply and/or the recruitment of colonising organisms. Acute or chronic impacts on communities and species reliant on the ecosystem may then occur, ranging from macroalgae and benthos to birds, fish (spawning, nurseries and adult habitat) and possibly mammals. All of this is inherently difficult to determine especially if information is lacking on these aspects. However more can be elucidated through consideration of hydrodynamics and geomorphology.

The hydrodynamic modelling of an estuary (e.g. New River) will allow various hypotheses concerning the mechanisms driving the changes of estuary condition to be explored and would produce better understanding of the relevant processes. A mechanistic model will enable mitigation options to be quickly and cheaply investigated, for example, bioremediation planting and de-reclamation.

Key questions to assess and therefore define model selection are the following:

1. To what degree is sediment and nutrient retained in the estuary?
2. How much is lost straight to sea?
3. What is the fate (geographically within the estuary) of nutrient and sediment?
4. What are the effects of past and present reclamation?
5. What are the effects of changing flow/flood regimes?

It is currently envisaged that a hydrodynamic model will be needed for all four main catchments in Southland i.e. New River Estuary, Jacobs River Estuary, Toetoes Estuary and Waiau Lagoon. However given the time and resources available the approach is currently carrying out resolute hydrodynamic modelling for New River Estuary (Delft 3D) and more course modelling for remaining estuaries in Southland (CLUES-estuaries). Comparative and sensitivity analysis may then be carried out using the CLUES estuaries and Delft 3D versions for New River Estuary. Assuming this outcome is robust enough CLUES-estuaries; in conjunction with the Estaury trohic Index (ETI) will be considered for use across Southland.

6. Source Tracking

This is to determine the origin of contaminants in the catchment to better understand the sources and relative contributions. The hydrodynamic model will provide further insight into this work as understanding the fate of the contaminants in the estuary receiving waters is fundamental to any approach to limit setting. The source tracking will additional provide empirical measurements to help validate the hydrodynamic work. Some sediment source tracking work has been completed for Oreti and Aparima catchments (Gibbs et al. 2014). Currently source tracking work is being considered for Nutrients and sediment.

7. Determination of Estuary Loads

This process will identify loads for given systems at specific time periods to provide a timeline relating estuary condition and loads (Fig. 5). A key step in this is to take the load information and filter it through information gained from morphometrics and hydrodynamics to express the 'retained load'. The retained load can therefore be defined as the load coming off the catchment multiplied by the capacity of the system to flush that load out to sea (or, conversely, to sequester it inside the estuary). This is particularly important in tidal lagoons which open and close (otherwise known as Intermittent Closed and Open Lakes and Lagoons [ICOLLs] e.g. Waituna and Lake Brunton). Therefore two different ecological condition gradients are needed to be formed one for tidal lagoons and another for ICOLLs due to the different flushing regimes. Additionally seasonality needs to be considered as loads may be predominantly from certain season and events.

To ensure that the limit-setting process links the ecological response of the estuary to relevant stressors (e.g. nutrient loads) a range of approaches have been proposed that convert the ecological condition endpoint for a particular value (e.g. the area of deep muddy sediments in the estuary should be <15% of the estuary area) to a load (or other) limit. These approaches include; predicting loads based on previous land use information, predicting loads based on load-response information from similar estuaries both in NZ and overseas.

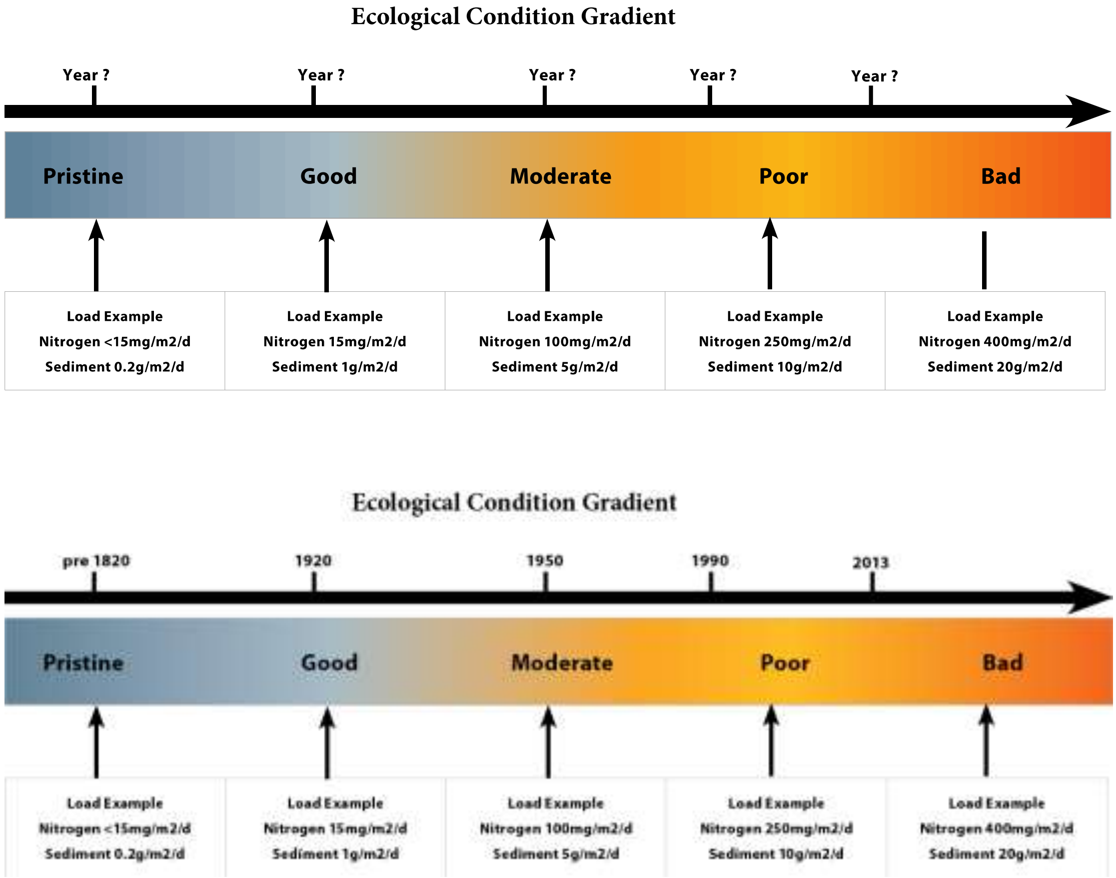

Figure 5. Further population of retained loads onto the ecological condition gradient.

Current loads for Southland estuaries (or just NRE) can be calculated from water quality monitoring data and the relative contributions from natural and land use sources can be estimated from existing models and information. Existing models (e.g. Catchment Land Use for Environmental Sustainability (CLUES), Sednet, Overseer, and other options) can be used to estimate historic loads based on best estimates of past land use data, including natural state. In addition, there are historical nitrogen load estimates going back many years (work done by the Land Use Inputs project, ES).

5. Estuary Review Work

Environment Southland (ES) have commissioned several independent expert reviews of their SOE monitoring programme and proposed Estuary Health Programme (EHP). Each of the reviews has considered different components and has presented recommendations to address a range of issues. Overall, all reviewers were in agreement that the ES State of Environment monitoring programme and proposed EHP correctly identify and target the key issues affecting the Southland estuaries addressed by the reviews. Many aspects raised by reviewers were considered by Environment Southland to be either minor, irrelevant, or reflecting a limited understanding of the purpose of the SOE monitoring programme. These aspects have been specifically detailed, with ES's response to each, in Appendix 1. Additionally a response from Wriggle Coastal Management Ltd has been added to the appendix (Appendix 2). It is noted that changes made and implemented following the Jenkins 2013 review were overlooked in the subsequent reviews conducted by both NIWA (Green M 2014; Townsend M & Lohrer D 2015) and Cawthron (Cornelisen C & Gillespie 2015) which meant many components of those reviews were redundant.

ES are subsequently satisfied that any issues identified in the SOE monitoring, or valid issues identified by reviewers, have now been appropriately addressed in the EHP through the following:

1. Modification and extensions to the SOE programme including additional robust statistical analyses.

2. Development of targeted supporting research related to estuary condition assessment e.g. documented condition ratings

3. Integration into the EHP, and specifically the ECG programme

4. Development of the NZ Estuary Trophic Index (ETI) and supporting documentation

4.1 Jenkins 2013

In 2013 Professor Jenkins of Melbourne University was commissioned by Environment Southland to review the Estuary State of Environment monitoring programme.

The scope of the review is as follows:

- Comments on the suitability of the methods for assessing ecosystem health
- Comments on sampling spatial/frequency sufficiency
- Comments on sampling representation sufficiency
- Comments on limitations of the methods
- Recommendations on future monitoring
- Comments on the strength of results and whether conclusions are justified for New River Estuary (Invercargill/Environment Southland) and Porirua Harbour (Greater Wellington Regional Council) as case studies.

4.2 NIWA 2015

As a first step in developing the ecological condition gradient approach, DairyNZ and Environment Southland contracted NIWA to (1) assess the ecological health of four Southland estuaries (Jacobs River Estuary, New River Estuary, Waikawa and Toetoes) using existing monitoring data, and (2) review the main drivers of estuary ecological health and water quality in the region. These drivers are nutrients and fine sediments.

The results of the two tasks were reported in two companion reports:

> ‘Drivers of estuary ecological health and water quality in the Southland region’
> (Green 2015)

> ‘A review of the ecological health and water quality in four Southland estuaries’
> (Townsend & Lohrer 2015)

4.3 Cawthron 2015

Cawthron were asked by ES in July 2015 to review the Ecological Condition Gradient (ECG), a key sub-component of the broader Estuary Health Project (EHP), and make recommendations on:

- The general approach and if it has merit
- Information that may need strengthening up
- Information that may be lacking altogether
- Limitations in the ECG approach

Cawthron’s letter report (5 August 2015) essentially falls into two parts:

- Part 1. General comments on the ECG approach (recommendations were not made in relation to specific ECG components).
- Part 2. High level comments and recommendations in relation to the wider EHP.

The specific issues and concerns raised during this plethora of reviews have been collated into a table in Appendix 1 and corresponding responses added.

6. Overall recommendations from reviews

This section encompasses general responses and comments with regard to recommendations contained in the reviews.

<u>Drivers of Estuary Ecological Health and Water Quality in the Southland Region</u>
(Green 2015)

Recommendations:

Nutrients

Refinement of the predictions of future trophic state and development of the ecological condition gradient for use in limit setting will require:

1) a better assessment of the way terminal-reach nitrogen loading rates convert into estuary water-column concentrations and the way water-column concentrations fuel algae growth and the associated development of secondary symptoms of eutrophication,

COMMENT: *Macroalgal growth is influenced by both water-column nutrients and nutrients that are released from sediments. However, the ECG approach does not rely on sediment nutrients to produce the nutrient load - ecological response gradient. It will be statistically tested in regard to the extent that it covaries with other potential responses to N load e.g. TOC, TS, redox potential, macroalgal cover. This aspect is being further considered within the context of the ecological condition gradient.*

2) assessing the store of nutrients in the estuary bed sediments and the importance of bed-sediment nutrient dynamics.

COMMENT: This aspect is being further considered within the context of the ecological condition gradient.

3) Tools that will assist are:
   - CLUES–Estuaries,
   - Delwaq delft 3D modelling + habitat modelling
   - Estuarine Trophic Index Tool

COMMENT: These tools are already contained within the Estuary plan. Currently the programme includes all these aspects. Consideration is being given to Delwaq. Habitat modelling has some very serious limitations that may be unacceptable. Not enough information is available on biogeochemical processes, species life ranges and ecological processes and interactions to conduct this work appropriately with confidence and with a quantification of uncertainty.

4) It is particularly important to understand the seabed nutrient dynamics when trying to predict how the estuary might respond to management of land-side nutrient sources. Improving our understanding of seabed nutrient dynamics in Southland estuaries will improve our ability to predict how estuaries will respond to management of land-side nutrient inputs.

COMMENT: This aspect is being further considered within the context of the ecological condition gradient.

5) Virtually nothing is known about restoration trajectories that might be followed by New Zealand estuaries following a reduction in land-side nutrient inputs

COMMENT: Using this lack of knowledge to argue no management response is invalid. If hysteresis is present it will be present regardless of the scientific or management approach. Without greater understanding of the systems and empirical measurements of the processes during hysteresis the lack of knowledge around restoration trajectories will probably remain. Hysteresis is likely to be present in these systems but there is lack of information to be able to define them. Regardless of the approach this is likely to the case and should be made apparent to decision makers. Additionally hysteresis is not relevant to systems that have not yet reached thresholds or which have not yet moved into an unacceptable state. The work is also to help manage less degraded systems as well as degraded. The Hysteresis story needs to be communicated well to decision makers, regardless of the approach it will likely be present.

Again, this aspect cannot be properly considered until the statistical work referred to above is completed.

Sediments

6) A process-based catchment sediment model is required to provide information on sediment loads and past trends in loads to the four study estuaries. Combined with an estuary sediment transport model that explains dispersal, accumulation and flushing of fine sediment, the loads will improve the understanding of drivers of estuary sediment health, which is currently rudimentary, and will assist with development of the ecological condition gradient.

COMMENT: *The concept of the estuary programme is to have the processed based approach – models etc. inform the ECG and vice versa. There are limitations to both but together there is greater certainty and understanding.*

Sednet was developed in Australia applied to the North island NZ and has not been applied in Southland. There is currently a large lack of information to conduct Sednet in Southland. It probably doesn't represent the processes in Southland sufficiently to warrant the application of Sednet. In particular bank erosional processes. Current work, as part of the wider science programme is collating information around bank erosion and other relevant processes in Southland. A sediment catchment model will likely then be selected based upon its appropriateness.

7) Predictions by a catchment sediment model of future trends in sediment loads will assist management in designing intervention.

COMMENT: *Agree – part of the wider science programme.*

8) Following the type of procedure devised by Green (2013), a catchment sediment model could be combined with a process-based understanding of estuary sediment transport patterns in a "source-to-sink" model that could be used to determine catchment sediment load limits that would achieve estuary sedimentation targets. The same type of model could be used to test and explore scenarios in a community collaborative process.

COMMENT: *Agree – however previous two points above apply. The Estuary Health programme has so far complete the hydrodynamic ,model and sediment particle transport module of Delft 3D. This will complete the estuary sediment modelling component but the catchment model is still to be fully determined (see above).*

<u>A review of the ecological health and water quality in four Southland estuaries</u>

(Townsend & Lohrer 2015)

Overall the reviewers conclude that the estuary SOE monitoring undertaken by Wriggle for ES:

- correctly assessed the key issues effecting the Southland estuaries reviewed,
- identified significant degradative changes over time,
- accurately ranked estuaries in terms of health,
- provided overwhelming evidence to support the presence of significant anthropogenically generated eutrophication and sedimentation

These conclusions provide a very strong endorsement of the Environment Southland estuary monitoring programme. The vast majority of the concerns raised in relation to the various methods, analyses, and interpretations of the data are attributable to the prioritisation of available resourcing towards the cost-effective detection of key issues, which has been successfully achieved.

The concerns raised in the review failed to consider the substantial additional work undertaken since 2013, which address the bulk of the issues raised. Consequently the vast majority of the largely minor concerns raised have already been addressed or can be very simply addressed through additional resourcing. The proposed Southland ECG, and the national Estuary Trophic Index (ETI) currently being prepared by NIWA and Wriggle (available early 2016), will provide further resolution of issues in relation to national consistency and validation condition indices and bandings.

It is noted that concerns relating to the lack of underpinning information to support indices and bandings appear to overlook the context in which they were developed - a suite of screening-level tools developed by Wriggle, on the fly and without funding, to help guide the assessment of individual estuary condition. They have been applied, with a range of caveats, to Southland's estuaries because NZ's government funded research providers have yet to provide regional councils with any meaningful national guidance on estuary assessment and management. It is both obvious, and explicitly stated, that further development and validation of the interim bands are needed, and the recommended response to the identification of the significant issues identified in Southland was to do precisely do that and is the basis for the proposed ECG.

Specific Review Recommendations:

1) Mine existing data, focusing on what we believe are the two most important and indicative data sets, namely, macroinvertebrate community data (fine scale), and 'nuisance' macroalgae cover data (broad scale). This may involve checks on the taxonomic resolution and quality of the macroinvertebrate data, and/or recalculation of the macroalgal coverage statistics from raw images.

COMMENT: *Agree, in part. It is clear that this would be valuable and has yet to be undertaken in a comprehensive manner for Environment Southland. This is proposed for inclusion in the ECG. However, the inclusion of mud as a key driver of estuary ecological condition also needs to be in the main focus, and is therefore proposed for inclusion in the ECG.*

2) Explore alternate macroinvertebrate sampling strategies to maximise their fitness-for-purpose moving forward. For example, it may be beneficial to cease macroinvertebrate monitoring at 'grossly eutrophic' sites (where rapid changes for better or worse are unlikely, and where general site conditions can be tracked with photos), and instead increase temporal resolution at the other fine-scale macroinvertebrate monitoring sites.

COMMENT: *Disagree. The reviewer's recommendation to cease macroinvertebrate monitoring of gross eutrophic sites and increase the temporal resolution at the low susceptibility sites, is contrary to fundamental risk assessment approaches, i.e. to identify and focus monitoring in the areas where change is most likely to occur in response to target stressors, and to minimise monitoring in low susceptibility zones where change is less likely. In shallow intertidal dominated estuaries, the main basin sites are located in low susceptibility zones where it is unlikely that any significant response to nutrient and sediment loads will occur (i.e. they are very well flushed and therefore limited by physical factors rather than nutrient and sediment loads). It also ignores the fact that the macroinvertebrates are the key ecological components of the monitoring programme and therefore the whole weight of evidence in terms of nutrient load/sediment abiotic condition/ecological response rests on them. To cease monitoring at such sites will directly compromise the ability to derive validated guidance on estuarine condition and establish management thresholds/targets (a critique made by the reviewers of the current programme). The proposed ECG recommends improving resolution within sediments at <u>both</u> low and high susceptibility sites.*

3) Conduct a comprehensive analysis of existing macroinvertebrate datasets, focusing on (i) changes in macrofaunal community composition over time, (ii) temporal trends in selected individual taxa, (iii) changes in site-specific environmental data and modelled/measured catchment loading information. There are a variety of advanced univariate and multivariate statistical modelling techniques that can be utilized to test for the existence of temporal trends and to analyse stress-response relationships while accounting for natural temporal cycles.

COMMENT: *This work is currently contained in the next steps for the Estuary Health programme and will be carried out in early 2016.*

4) Conduct a comprehensive analysis of patterns of nuisance macroalgae coverage in estuaries, with a focus on (i) trends over time and how they correlate with trends in modelled/measured contaminant loadings from the catchment, (ii) an examination of the role of internal estuarine hydrodynamics, and degree of match between water circulation patterns and the spatial distribution of macroalgae within estuaries, and (iii) other contributing factors such as benthic habitat/substrate types, interactions between turbidity and nutrients, etc.

COMMENT: *This work is currently contained in the next steps for the Estuary Health programme.*

5) Quality assurance / quality control procedures are needed throughout the programme, including better standardisation of field methods, macroinvertebrate identification checks (e.g., 10% of samples; Hewitt et al. 2015), and regular critical review of technical reports. Independent reviewing of reports could be done at minimal cost via a number of different avenues, for example, reciprocal relationships with Regional Councils or small contracts to experts identified by the Coastal-SIG.

COMMENT: *Agree; the ES SOE estuary programme already uses QAQC procedures equivalent to those very recently proposed for the first time in NZ to standardise sample collection and analysis (Hewitt et al. 2015). Reviewing of reports is currently undertaken by Environment Southland specialist staff who contract external reviewers as considered necessary (e.g. Jenkins 2013). Further, wider review on generic programme and reporting components is provided by other Councils as part of their review processes (GWRC, NCC, TDC, MDC) either internally, or through contracted review by research providers (NIWA, Cawthron, Landcare), or other consultants.*

Environment Southland's Estuary Health Project and implementation of the Ecological Condition Gradient approach

(Cawthron 2015)

With regard to the Ecological condition gradient (ECG) approach (Part 1),

Cawthron endorse the general ECG approach proposed by ES. No changes to the ECG are recommended beyond ensuring relevant review comments are addressed as part of ECG reporting. Some limitations have been highlighted by Cawthron and are predominantly minor and readily addressed. These specific points have been captured in Appendix 1.

and conclude that it:

- has merit and will assist ES in the process of limit setting.
- addresses the most significant estuarine health issues and valuable data will be collected and reported for Southland estuaries through its implementation.

Potential ECG limitations have been addressed by way of general comments only. In the absence of recommendations, the reader must make a subjective assessment of the significance of the comments made. It will be very difficult for a non-specialist reader to decide what comments are relevant or important given that many of them are minor, reiterate what is already proposed, lack relevance to the ECG, or are based on incorrect assumptions. Specific points have been captured in Appendix 1.

A significant concern raised with regard to the ECG by Cawthron is they are "...not convinced that relevant nutrient and sediment load/ecological response relationships can be derived from point-in-time measures ...". Cawthron correctly identify the high importance of this relationship, without which it will not be possible to establish an ECG. However, the ETI has already demonstrated this relationship exists for shallow intertidally dominated type estuaries in NZ (i.e. New River, Jacobs River), and therefore it is clear that screening level load limits can be developed for Southland using the proposed ECG approach.

With regard to the wider Estuary Health Programme (EHP) approach (Part 2), Cawthron make three high level recommendations:

1. Develop an overarching framework that identifies how various resource management and monitoring efforts integrate and contribute toward addressing objectives in the NPS-FM as well as the NZ Coastal Policy Statement.

2. Consider influences of the estuary on the surrounding coastal environment to ensure protection and management is integrated across the Council's full jurisdictional boundary (land, estuaries, and the coastal marine area).

3. Better define the goal and objectives of the ECG as they align with other council initiatives to assist in identifying linkages between work being carried out and what ES is seeking to ultimately achieve.

All three recommendations are considered useful policy steps that would strengthen the EHP by ensuring it is linked within broad Council planning objectives. However they are not considered integral to, or a prerequisite for, the effective implementation of the EHP, nor the ECG. This being said these recommendations should be incorporated into the programme and given due consideration.

The Cawthron review of the 7 primary 'tool' steps described in the EHP did not identify any missing or unnecessary steps. Cawthron's comments have been rephrased below as recommendations, and a response to each provided.

Reccommedations:

1) Drivers of Estuary Condition in Southland

- Use existing data and knowledge to identify key drivers of change in Southland estuaries prior to carrying out further monitoring.

COMMENT: Directly addressed in the ECG through Step 1 ("Strawman") and Step 2 ("Ironman") [see page 2 of Wriggle proposal]. No action/changes to ECG necessary.

2) Determination of Estuary State

- Determine current estuary state, and use any information on trends in condition to assist in linking response to stressors.

COMMENT: Directly included as a core part of Step 1 ("Strawman") and Step 2 ("Ironman") of the ECG [see page 2 of Wriggle proposal]. No action/changes to ECG necessary.

- Attempt to use other indicators that link more broadly with ecosystem services and community values (e.g. kai moana quality / abundance, bird populations) to more accurately reflect the community's views of what constitutes a "pristine" versus "bad" estuary.

COMMENT: Issue already addressed during EHP development. Council determined that the initial focus is on ecological condition, and that community perspectives will be incorporated *subsequent to the proposed initial ECG work. Further, page 3 of the Wriggle proposal notes that these aspects will be included as follows: "....in the absence of quantitative data linking impacts to estuary-wide ecological condition (e.g. sediment physicochemistry-bird/fish relations), the condition gradient for each of these indicators will be determined by a qualitative approach based on expert opinion...." . No action/changes to ECG necessary.*

3) Characterisation of Estuary Morphometrics

- Important and required step which should include both flushing and assimilation capacity.

COMMENT: This is a well understood aspect and is inherent in the ECG framework as proposed. Flushing and assimilation capacity is specifically addressed in the Estaury trophic index (ETI). The ETI places significant emphasis on the importance of dilution and flushing when assessing both susceptibility to eutrophication and in selecting appropriate monitoring indicators and defining limits/thresholds. This work will be further supported by hydrodynamic modelling (see below). No action/changes to ECG necessary.

4) Hydrodynamics

- Apply a step-wise approach to hydrodynamic modelling, with an initial focus on heuristic models (e.g. box models).

COMMENT: This is the approach being taken. The hydrodynamic model is initially proposed for use primarily in heuristic modelling of dilution, flushing, and sediment deposition/retention to inform load setting decisions in the manner recommended. ES have decided on the modelling approaches based on expert input from NIWA (and others), and understand requirements for additional modelling steps should they be required in future. No action/changes to ECG necessary.

5) Source Tracking

- Can be very useful for prioritising, defining spatial extent of stressors (footprints), and identifying activities contributing to change.

COMMENT: Sediment source tracking has already been undertaken by Max Gibbs (reported on in 2014). The need to address issues regarding the interpretation of the results (e.g. sensitivity of markers to land use changes, and time lags associated with sediment delivery from land to estuary) is recognised. The hydrodynamic modelling will help provide another facet to the source tracking work. No action/changes to ECG necessary.

6) Determination of Estuary Loads

- High priority to obtain accurate estimates of loading changes over time. Provide better definition of approaches to linking multiple drivers of contaminant loading to estuary state.

COMMENT: This is a major component of the EHP and was collectively agreed that the approach would use a modified CLUES model [see page 6 of Wriggle proposal]. NIWA are *contributing significant funds to improving CLUES outputs, including seasonal predictions of estuary nutrient concentrations, and the ability to derive loads from identified land use activities. ES is developing historical land use layers to be used for predicting historical loads. These more refined loading components are expected to be included in the ECG approach in later stages of the project. Validation data are currently being collected by ES. No action/changes to ECG necessary.*

7) **Formulation of 'Ecological Condition Gradient'** (see also previous comments under "Potential Limitations of the ECG")

The following specific high level recommendations were made by Cawthron:

- Set realistic expectations regarding outcomes of this ECG work and the ability to set appropriate load limits.

COMMENT: It is considered that this has been done based on a sound and realistic appraisal of current knowledge. No action/changes to ECG necessary.

- Place the ECG within a broader resource management and monitoring framework to ensure decisions and management steps are appropriately linked to policy goals and objectives and community values.

COMMENT: This has been requested from ES policy staff. No action/changes to ECG necessary.

7. Summary

Overall, all reviewers were in agreement that the ES State of Environment monitoring programme and proposed EHP correctly identify and target the key issues affecting the Southland estuaries. Many aspects raised by reviewers were considered by ES to be either minor, irrelevant, or reflecting a limited understanding of the purpose of the Estuary Health Programme and/or the SOE monitoring programme. These have been specifically addressed in Appendix 1.

The remaining aspects which are deemed to be of importance are further iterated below for more clarification.

Nutrients

The Estuary Health programme needs to consider:

a. An assessment of the nutrient dynamics taking into consideration water-column concentrations and sediment-nutrient dynamics. The ECG is initially approaching the nutrient load-ecological response from a statistical approach; further consideration will be given to this aspect at later stages of the Estuary Health programme. Further consideration will be given to biogeochemical processes with regard to nutrient dynamics. This may be via a conceptual and measured approach to further assess the need for a biogeochemical model.

b. Consider lag times for nutrients in dynamics and hydrology

Sediments

The sediment project being overseen by the Soils & Freshwater Team Leader needs to consider:

c. means to assess past and current loads (and trend) to the four study estuaries with an appreciation of contribution from different processes.
d. means to assess future trends in sediment loads to assist management intervention
e. means to test and explore scenarios in a community collaborative process
f. consider legacy effects and lag times for sediment

Policy Development

g. Develop an overarching framework that identifies how various resource management and monitoring efforts integrate and contribute toward addressing objectives in the NPS-FM as well as the NZ Coastal Policy Statement.
h. Consider influences of the estuary on the surrounding coastal environment to ensure protection and management is integrated across the Council's full jurisdictional boundary (land, estuaries, and the coastal marine area).
i. Better define the goal and objectives of the ECG as they align with other council initiatives to assist in identifying linkages between work being carried out and what ES is seeking to ultimately achieve.
j. Place the ECG within a broader resource management and monitoring framework to ensure decisions and management steps are appropriately linked to policy goals and objectives and community values.
k. Enhancement should be considered within the context actively mitigating loading for estuary recovery. A remediation project is underway for New River Estuary but consideration will extend to Jacobs River Estuary which is on a very similar trajectory. This is composed of three steps; a workshop, feasibility study, and finally on ground action.

These recommendations should be further considered as part of the wider Science programme and the wider Water land 2020 Environment Southland programme which addresses the National Policy Statement for Freshwater Management.

8. References

Cornelisen C & Gillespie (2015) Environment Southland's Estuary Health Project and implementation of the Ecological Condition Gradient approach. Prepared for Environment Southland by Cawthron.

Gibbs M, Olsen G & Stewart M (2015) New River Estuary sediment sources tracking pilot study. Prepared for Environment Southland by NIWA.

Gibbs M, Olsen G & Stewart M (2014) Jacobs River Estuary sediment sources assessment. Prepared for DairyNZ by NIWA.

Green, M.O. (2013) Catchment sediment load limits to achieve estuary sedimentation targets. *New Journal of Marine and Freshwater Research*, 47(2): 153–180.

Green M (2015) A review of the ecological health and water quality in four Southland estuaries. Prepared for DairyNZ and Environment Southland by NIWA.

Greenfield, B., Hewitt, J., Hailes, S. (2013) Manukau Harbour ecological monitoring programme: report on data collected up until February 2013. Prepared by NIWA for Auckland Council. *Auckland Council technical report*, TR2013/027.

Hewitt, J.E., Hailes S.F., Greenfield, B.L. (2015) Protocol for Processing, Identification and Quality Assurance of New Zealand Marine Benthic Invertebrate Samples. Report prepared by NIWA for Northland Regional Council.

Jenkins, G. (2013) Review of the Estuarine Monitoring Programme in New Zealand with emphasis on the New River Estuary and Porirua Harbour. Department of Zoology, University of Melbourne. Prepared for Environment Southland.

Parkes, S., Lundquist, C. (2014) *Central Waitemata Harbour Ecological Monitoring: 2000-2014*. Prepared by NIWA for Auckland Council.

Robertson, B.M., Stevens, L.M. (2013A) *New River Estuary: Fine scale monitoring of highly Eutrophic arms 2012/2013*. Report prepared by Wriggle Coastal Management for Environment Southland: 27.

Rodil I.F., Lohrer A.M., Hewitt J.E., Townsend M., Thrush S.F., Carbines M. (2013) Tracking environmental stress gradients using three biotic integrity indices: Advantages of a locally-developed traits-based approach. *Ecological Indicators,* 34:560–570.

Snelder, T., Fraser, C., Hodson, R., Ward, N., Rissman, C., Hicks, A. (2014) Regional Scale Stratification of Southland's Water Quality – Guidance for Water and Land Management. *Aqualinc Report,* No. C13055/02, prepared for Southland Regional Council, March 2014, Christchurch.

Townsend, M., Simpson, J., Greenfield, B.L. (2012) *Upper Waitemata Harbour Ecological Monitoring Programme: 2005-2012.* Prepared by NIWA for Auckland Council.

Townsend M & Lohrer D (2015) Drivers of Estuary Ecological Health and Water Quality in the Southland Region. Prepared for DairyNZ and Environment Southland by NIWA.

9. Appendices

Appendix 1 - Table of Commentary and responses

No.	Responsibility	Concern / Recommendation	Source	Comment	Action
The approach of the ecological condition gradient					
A1	Wriggle	Avoid putting too much weight on one indicator (e.g. Seagrass).	Cornelisen & Gillespie (2015)	The ETI (which underpins the ECG) is built on a multi-indicator approach recognising the limitations of single indicator metrics. Seagrass is an indicator that can be limited in many ways, both natural and human influenced. The benefit of the ECG approach is that if relationships can be established where seagrass beds have significantly diminished when sediment or nutrient loads have increased, it does provide a very clear indicator of estuary degradation. This relationship exists in New River Estuary.	None Needed Currently being addressed by ECG
A2	Wriggle	There may be concerns regarding the applicability of Southland load limits being applied elsewhere in NZ	Cornelisen & Gillespie (2015)	This is based on a false assumption that ES are developing national load limit criteria, rather than load limits for specific Southland estuaries based on estuary response relationships from a national data set.	None Needed
A3	Wriggle	Each estuarine system should be assessed individually with respect to ecosystem values that it supports, before implementing the ECG. For example, the relationship between trophic condition and anthropogenic stress is specific to each system, and may vary significantly between systems. Some systems may also be naturally more productive than	Cornelisen & Gillespie (2015)	The ECG takes a certain estuary eutrophication susceptibility type - shallow intertidal dominated tidal lagoon estuaries - as the first type being considered (data set includes 20 plus example estuary types). Within this type it can therefore be expected that the nutrient load / trophic response for estuaries within this type to be similar. The approach also takes into account hydrodynamic mediating factors which influence some aspects of susceptibility. Within this framework, each estuaries trophic state and nutrient load is assessed individually.	None Needed Currently being addressed by ECG

		others.			
A4	Wriggle	Each estuary should be assessed with respect to overall coastal environment, especially impact of SS on coastal areas.	Cornelisen & Gillespie (2015)	This is beyond the scope of the ECG by Council. It is also extremely likely that by addressing estuary issues, the potential impacts on the wider coastline will be significantly mitigated considering the prevailing coastal conditions in Southland. Default to the most sensitive environment and manage to that, i.e. the estuary.	None Needed - Outside scope
A7	Wriggle	It is important that the development of the ECG utilises the ETI and that it is appropriately validated by robust science. This includes appropriate validation of all ecological indicators used in the project. Tools that will improve predictions and assist with limit setting are available or in development, and these include the CLUES–Estuaries tool for predicting estuarine "potential" nutrient concentrations under different catchment land uses, a macroalgae growth model being developed by NIWA, and an "Estuarine Trophic Index" currently being developed under an Envirolink grant.	Cornelisen & Gillespie (2015) Green (2015) (p5)	Because the same authors are involved in both the ETI, the ECG, and PhD validation studies, direct integration and utilisation is guaranteed. The ETI, the ECG and are using the same metrics. The current programme intends to approach the subject by multiple lines of evidence. This includes using Delft 3D modelling, CLUES-estuaries and the ETI.	None Needed Currently being addressed by EHP None Needed Currently being addressed by EHP
A8	Wriggle	Macroalgae growth may be the product of multiple stressors, not just nutrient load, so multiple indicators need to be taken into account.	Cornelisen & Gillespie (2015)	The ECG load - response relationship for the chosen estuary type considers both nutrient and sediment load as the major stressors, but also includes a range of other mediating influences e.g. salinity, hydrological characteristics, mud content.	None Needed Currently being addressed by ECG

A9	Wriggle	Need to obtain more temporally resolute data to set load limits. If Environment Southland is to move towards limit setting of nutrient inputs and the identification and management of nutrient sources, it likely that a comprehensive monitoring programme will be required to: a) monitor the nutrient status moving forward b) to refine and validate model predictions, c) evaluate and report compliance and identify non-compliance. Nutrient load information needs to focus on lowland rivers and river mouths.	Cornelisen & Gillespie (2015) Townsend & Lohrer (2015) (p24) Cornelisen & Gillespie (2015)	The ECG relies on benthic ecological response, not the water column, and therefore is a good integrator of intra-annual variability. Therefore there is expected to be a strong link between annual nutrient loads and ecological response. However, assessment of winter vs the rest of the year loads, is recommended for inclusion in the later stages of the project. Historical load estimates are being developed by ES along with the continuous network which will monitor inputs through time. This is being addressed as part of the surface water quality continuous monitoring network.	None Needed Currently being addressed by ECG None Needed currently being addressed by wider Science Programme None Needed
A10	Wriggle	Condition rating rationale requires further scientific scrutiny before it can be accepted as a management tool.	Townsend & Lohrer (2015) (p14,15) Cornelisen &	The seagrass condition rating is an appropriate measure of change within a specific estuary (as currently applied), but not for a comparison of change between estuaries (not used for this). It is also clear that different estuaries have variable covers of	None Needed Currently being addressed by ECG

		The use and validity of the seagrass condition rating is uncertain.	Gillespie (2015)	seagrass and that the extent of seagrass may not be a reliable measure or eutrophication related change. Therefore, a change from estimated likely natural state cover is a useful measure of seagrass change, but the relationship to eutrophication needs to be evaluated on an estuary specific basis with regard to other specific drivers of possible change (particularly sedimentation rates). The ECG will utilise Condition Ratings developed and supported as part of the ETI.	
A11	Wriggle	Revisit and strengthen soft sediment habitat assessment.	Townsend & Lohrer (2015) (p13), Cornelisen & Gillespie (2015)	This is specifically addressed in the ECG by the inclusion of extensive particle grain size analyses to more accurately delineate boundaries between substrate types.	None Needed Currently being addressed by ECG
A12	Wriggle	Sediment trapping in the estuary will change with time and with reclamation, which may cause more SS to be out-welled from the estuary.	Cornelisen & Gillespie (2015)	Hydrodynamic modelling will allow SS to be addressed, and validated where WQ data are collected. Coastal habitat is beyond the scope of the ECG. Because Council have previously decided that the EHP will focus on development of an estuary ECG and not encompass the wider coastal environment, this comment is irrelevant to the ECG	None Needed -Outside scope
A13	Wriggle	Standardised quality bands may be contentious when applied to other estuaries in NZ Lack of validation of the values used to define the 'bands' of estuarine health conditions.	Cornelisen & Gillespie (2015) Townsend & Lohrer (2015) (p4)	The ECG will utilise multiple Condition Ratings (or standardised quality bands) developed and supported as part of the ETI for estuary types from throughout NZ and will combine ratings provide an overall estimate of trophic state rather than put undue weight on individual weightings. This supporting indicator approach will use the demonstrated relationship between loads and response to define the thresholds at which significant changes in trophic condition are observed. Notwithstanding this, the ECG	None Needed Currently being addressed by ECG

				is being developed specifically for Southland so is not attempting to produce NZ wide ratings.	
A14	Wriggle	There is no need to expend effort linking environmental parameters to species of interest; this work has already been done.	Cornelisen & Gillespie (2015)	Much of the specific work referred to by Cawthron excludes fundamentally important measures of sedimentation and organic enrichment (e.g. TOC, RPD, macroalgae) that are directly relevant to the ECG and load limit setting framework. They are also based primarily on relatively few estuaries from the Nth Island, and commonly target sites with elevated metal contaminants (specifically Auckland, which is experiencing different issues to Southland).	None Needed Currently being addressed by ECG
A16	ES	A better estimate of catchment sediment loading over time is required.	Cornelisen & Gillespie (2015)	This is partly addressed by the sediment modelling project being run by the Soils & Freshwater Team Leader. Additional sediment cores may be needed to understand historical sediment loading rates.	Currently being addressed by wider Science Programme
A17	ES	Clearly define the goal and objectives as they align with other council initiatives.	Cornelisen & Gillespie (2015)	Always a helpful exercise.	Currently being addressed by EHP
A18	ES	Define community values early in the limit setting process.	Cornelisen & Gillespie (2015)	ES policy team has decided to take the science to the community, rather than use community knowledge to tailor the science. Refer to 21.	None Needed -Outside scope and not feasible at this time
A19	ES	Develop overarching framework that identifies how various resource management and monitoring efforts integrate and contribute towards addressing objectives in the NPS-FM as well as the NZ coastal policy statement.	Cornelisen & Gillespie (2015)	This has been requested from ES policy staff. Ongoing work.	Currently being considered by EHP
A20	Wriggle & ES	Identify measure and actively mitigate loading and enhance the rate at which estuaries recover.	Cornelisen & Gillespie	Remediation project is underway for New River Estuary. This is composed of three steps; a workshop, feasibility study, and finally on ground action. NRE	Currently being considered - this will involve political

			(2015)	specific hydrodynamic project will help. Potentially a PhD for better understanding multi-stressor response to species.	decisions and involvement.
A21	ES	Map the use of hydrodynamic model output so everyone has a clear understanding of aims, outputs and pathways.	Cornelisen & Gillespie (2015)	The hydrodynamic model is being used to better understand fate of contaminants. This will give a calculation as to the retained load in different estuaries. Very important when considering the comparison of systems against each other.	None Needed Currently being considered by EHP
A22	ES	Nutrient tracking will require a biogeochemical model.	Cornelisen & Gillespie (2015)	This is beyond the scope of the project. The ECG is less concerned with the dynamic of internal nutrient sources and more with how catchment load affects the overall state of the estuary.	None Needed - Outside scope
A23	Wriggle & ES	Further populate ECG with local information.	Cornelisen & Gillespie (2015)	Council have decided upon another approach to community science and community engagement. This may change in the future, but this needs to be addressed by the policy division. It would be ideal to further populate the ECG with local information but will need policy at ES to collate the information during the values project.	None Needed -outside scope
A24	Wriggle	How will the ECG take into account sediment and nutrient lag times?	Cornelisen & Gillespie (2015)	The ECG is developing an Ecological Condition Gradient which relies on sediment and nutrient load data provided by ES. The nutrient sediment load - trophic response relationship is built on the measured trophic response to validated modelled catchment nutrient loads entering the estuary. The ECG compares relative differences in nutrient inputs to trophic response, and therefore provides a robust comparison as long as similar methodologies to estimate N loads are used for each estuary e.g. NIWA CLUES model. In the initial phases, current CLUES default loads will be used to produce the Strawman. It is expected that ES will provide more refined load estimates as the project develops.	Currently being considered -being addressed by wider science programme

A25	Wriggle	A processed based understanding could provide a more robust and nuanced method for setting limits than ecological condition gradient which is based solely on correlation rather than causative relationships.	Green (2015) (p5)	The concept of the estuary programme is to have the processed based approach – models etc. inform the ECG and vice versa. There are limitations to both but together there is greater certainty and understanding. Correlation is the first step towards causative relationships. Modelling a system does not automatically mean causation is understood.	None Needed
A26	Wriggle & ES	Environment Southland intends taking an "ecological condition gradient" approach to determining catchment nutrient and sediment load limits that are required to achieve estuarine objectives. This involves identifying a number of estuarine environments that lie along a gradient of very healthy to very degraded, and then developing a matching gradient of sediment and nutrient loadings. The idea is that it will be possible to move any given estuary to a new location on the continuum (e.g., closer to the "healthy" end) by reducing the loads according to the matching contaminant continuum. This may be achievable if there is a causative relationship between the contaminant loading and the indicators of ecological condition (as opposed to a non-causative correlation), and there is no hysteresis in the system response to a reduction in contaminant loading.	Green (2015) (p4,5)	Environment Southland is conducting this work to better understand systems in order to better inform community during limit setting and conduct more appropriate and effective resource management. Without understanding systems better there cannot be managed appropriately. The objectives for estuaries have not been defined. However some scientific measures have being used to differentiate ecological thresholds and understand drivers. To achieve this will take a range of approaches from modelling to empirical measurements and defining correlations. Hysteresis is likely to be present in these systems but there is lack of information to able to define them. Regardless of the approach this is likely to the case and should be made apparent to decision makers. Additionally hysteresis is not relevant to systems that have not yet reached thresholds or which have not yet moved into an unacceptable state. The work is also to help manage less degraded systems as well as degraded. The Hysteresis story needs to be communicated well to decision maker, regardless of the approach it will likely be present.	None Needed

				It has not been suggested that a system can be moved to another state purely based on load reductions.	
A27	ES	Studies have recently been conducted to identify sources of sediment that deposit in some Southland estuaries. For instance, Gibbs et al. (2014) used the CSSI technique to identify sources of sediment that deposit at four locations in Jacobs River Estuary. Gibbs et al. considered the contributions of three "external" sources (the Aparima River, the Pourakino River and the coast outside the estuary) as well as "translocation" of sediment between the four sites in the estuary. The major result was that virtually no new catchment sediment was depositing at any of the sites, with most of the sediment at each of the four sites coming either from the coast or from the other sites within the estuary. Gibbs et al. attributed this result to the short residence time of the estuary, which results in efficient flushing to the coastal ocean of the bulk of any sediments delivered in freshwater runoff.	Green (2015) (p17)	In actual fact the conclusion from the report was that: "The similarity in the source proportions by land use at these two locations suggests that the sediment deposited in the estuary has been moved around the estuary by tidal currents, which mix the source materials together into consistent proportions." – Gibbs et al. (2014) This does not mutually exclude new deposition. Though the coast is a major contributor of sediment; the study also goes into removing the coastal signature (i.e. sand, samples included all fraction sizes) as the material is predominantly sand. The statement above is based on when removing the coastal signature. The statement '……virtually no new catchment sediment was depositing at any of the sites..' is not supported and is not contained within the cited report.	None Needed

A28	Wriggle & ES	Figure 3-1 does not show any clear relationship between the annual suspended-sediment load and the sedimentation condition grade in either of the two estuary types represented in the figure. Snelder et al. surmised that the reason might be that the fate of sediments in estuaries is complex (particularly the degree to which sediments are trapped or flushed) and not well represented by the simple estuary types. They also noted that the regression model for the suspended-sediment loads "performed poorly". Given the result from Figure 3-1 and the lack of confidence in the suspended sediment loads, it does not seem defendable to infer trends in estuary "sediment health" from trends in freshwater suspended-sediment loads, which Snelder et al. (2014) had intended.	Green (2015) (p18)	Clearly more work is needed to better define sediment retained loads for the systems which was not done in the analysis. This is the intention of the estuary health programme to better understand retention of sediment in these systems and use modelling and ECG to gain greater clarity. The work referred to in the comments is very coarse and was not intended to serve as the finishing product for the EHP. Additionally, consideration was not given to the Waiau which is a highly modified system due to the hydrological power scheme and can therefore be considered an outlier. The Waimatuku can also be discarded as it relies on a slightly different monitoring approach. It could be argued that in fact there are interesting potential relationships in figure 3.1. despite the uncertainty, lack of consideration of retained load and assumption there is linear relationship. This shows promising signs which warrant further work.	None Needed
A29	Wriggle	Use additional information (e.g. Mahinga kai, bird populations) When determining estuary state.	Cornelisen & Gillespie (2015)	The lack of data, and NPS related time constraints have prevented this from becoming a major part of the ECG. These indicators are ideal for setting limits according to estuaries. However it is only possible to produce this work based on scientific indicators as opposed to community indicators. It will therefore be information that helps with The limit setting process and also is a necessary step towards management of these systems in Southland. With values defined, several years of data will be	None Needed - Outside scope

				needed to derive relationships --- this is not currently feasible with the timeframes given.	
The suitability of the Monitoring data					
B1	Wriggle	Sediment accumulation rates are inconsistent and problematic • Data from Bushy Point in New River Estuary is unreliable and should be removed from consideration. • As multiple sedimentation methods are used and issues of reliability may vary depending on technique, site, and from year to year, it is difficult to discern which historic sedimentation measures are valid and which are flawed. A fuller evaluation of historic data should be undertaken. Reports do not indicate which version of the technique is used at which sites. • Greater distances between marker stakes (i.e. 5m), will help to minimise the effects of external disruptions. Using a single reliable method at all sediment sites for comparisons between sites/estuaries is a desired	Townsend & Lohrer (2015) (p4,11)	The reviewers have incorrectly assumed how sediment plate data are measured in reaching this conclusion. To avoid the obvious issues postulated by the reviewer, the following measures have been used since the programme was established: A 2.5m straight edge is laid across each plate and settled to reflect the average sediment level across the site. This evens out small scale surface irregularities and completely avoids the issue of localised scouring above the plate (e.g. from macroalgae that may get caught on marker posts). Mulitiple measures are then made of the depth to the underlying plate to account for possible variance in the level of the plate. The straight edge is then relaid and measurements are repeated (3 measures made per site). Because of the high level of repeatability of these within plate measures, all measures are averaged in the field and a single plate measure reported. Measured depths are also able to be cross checked by measuring average surface sediment levels compared to marker posts installed at each site (each driven in to a measured height above the sediment surface). In addition, to check for potential subsurface plate movement (which has never been detected) the straight edge is placed on top of the marker post and the depth to the buried plate measured and compared to the baseline measure. The ECG proposes the installation of custom designed screw anchored plates without surface	None Needed Currently being considered by ECG

		outcome. • A photo record of each site/plate at the time of sampling would be a useful in the evaluation of reliability with respect to external influences.		marker posts (relocated by GPS and metal detector). The approaches described above have consistently measured sediment levels to a high level of accuracy from a range of estuary types thoughout NZ. The method is is recognised/applied internationally, and has been validated extensively throughout NZ by many councils, and was initiated in Southland following initial method development by NIWA and Waikato Regional Council.	
B2	Wriggle	Need to standardise broadscale surveys to a tidal height area (i.e. the minimum visible area throughout time), so values are comparable. Variation in total area surveyed is point of concern Ground truthing of methods to categorise habitat cover. The intensity of the sampling should be recorded. How accurately can observers categorise cover? Variation of designation of habitat due to change of observer?	Jenkins (2013) (p5,8) Townsend & Lohrer (2015) (p9,p13)	Agreed. It is important to emphasise that relative measures (percent change) have been used to account for differences between surveys in a consistent manner. However, small differences in extent are present, most commonly due to variable photographic coverages or improvements in mapping detail over time. In the ECG where repeat surveys have been undertaken (by the same observers) within an estuary, the estuary boundary will be standardised as closely as possible to the most accurately mapped layer. Any gaps with previous coverages will be interpolated using local knowledge and filled retrospectively to provide the most comprehensive cover possible with the available data.	None Needed Currently being addressed by ECG
B3	ES & Wriggle	Temporal frequency of sampling, ideally sites would be sampled more than once per year so that interannual variation could be factored in.	Jenkins (2013) (p7,9) Townsend & Lohrer (2015) (p19)	This has not been conducted to date due to financial reasons. This being said the temporal frequency of the sampling is in line with that in the literature. Jenkins further says that once sufficient numbers have been collected the data can be tested for trends over time, overcoming the issue. “Time series is sufficient to establish trends of degradation.”	None Needed Unable to address due to financial constraints

B4	ES	The point has been reached where management targets need to be set for nutrient and sediment inputs. Determining these targets requires research and funding, particularly focussed on modelling the system. There is a need to measure catchment inputs and develop guidelines for acceptable inputs that can be managed. To do this will most likely require the use of biogeochemical models of the estuaries and their inputs.	Jenkins (2013) (p12)	It is considered that the Water and Land 2020 programme being currently undertaken by the council is the vehicle by which these points will be addressed. This is being addressed by the NPS science programme at ES. Currently Oct 2015 the Delft 3D hydrodynamic model (hydrodynamics + sediment particle tracking module) is being constructed. Careful consideration should be given to whether biogeochemical processes are appropriately represented before trying to model ecological processes.	Currently being addressed by wider council WAL2020 Programme Further consideration needed within the EHP
B5	Wriggle	Where mean values of indicators are reported, it is imperative that error estimates (including error bars on graphs) are also included. Interpreting temporal trends and evaluating the significance of differences between sites was often difficult due to a poor characterisation of data variability Regression analysis (e.g., ordinary least squares regression) could be used to test for trends in sediment properties, macrofauna and contaminants. For most estuaries there are low number of data points, but statistical power will increase over time. Techniques are available to examine cyclical behaviour of macrofauna, or spatial auto-	Jenkins (2013) (p6,9,10) Townsend & Lohrer (2015) (p4,12,22)	These aspects are currently being address by the ECG approach, specifically in the first steps of mining data and assessing for relationships.	None Needed Currently being addressed by ECG

		correlation if sampling frequency is increased to multiple times per year (Townsend et al. 2012, Greenfield et al. 2013, Parkes et al 2014), though there are obviously fiscal costs associated with additional sampling and analysis. Future reporting should include statistical analysis (both univariate and multivariate), including analyses of the relationships between abiotic and biotic variables. Improvements to analyses could include; DISTLM or Canonical analysis of principle co-ordinates as well as other PRIMER functions to see if the percentage mud or other environmental variable explain the variability seen in the community data. SIMPER analysis (PRIMER) could be used to look at species which contribute to the differences in in community structure between sites/times. We recommend removing fish taxa and nematodes (meiofauna) from the analysis.			

B6	ES	There are still technical details that are absent that would be useful for method evaluation, for example, details of the processing/drying of heavy metal samples, and how salinity and grain-size are measured.	Townsend & Lohrer (2015) (p9)	Samples have been processed through an IANZ accredited laboratory with the methods in the appendices of all the historic reports.	None Needed
B7	Wriggle	With the data available, trends in Southland estuaries have not been quantitatively measured or formally tested and are judged from visual observations, that is, comparing a recent measurement with historic values and deciding whether they are commonly higher or lower	Townsend & Lohrer (2015) (p19)	This aspect is irrelevant to the ECG because the ECG is designed to match N loads to estuary response, and not present an analysis of change within an estuary over time. Notwithstanding this, there is no disagreement among reviewers about trends reported in previous assessments, and that the previous reports recommended further work to more fully quantify the trends evident.	None Needed Currently being addressed by ECG
B8	Wriggle	Use of the term Redox Discontinuity Potential (RDP), when in fact aRDP was measured	Townsend & Lohrer (2015) (p9)	Literature shows a disparity between the two measures. However wriggle addressed this by applying in situ measures to derive measures and spot audit checks during data collection.	None Needed Currently being addressed by ECG
B9	Wriggle	Macroalgal percentage cover or the total area coverage (ha) of an estuary will not necessarily be tightly related to the degree of nutrient loading The relationship between physical/chemical variables and their effects on macroinvertebrates is not well established. 'Causality' can be difficult to verify, but showing close correlation between environmental factor/stressors and changes in the community is a useful starting point.	Townsend & Lohrer (2015) (p21,23)	Speculation that has not been tested, but is proposed to be tested in the ECG. Rather than coverage *per se*, other components of macroalgae can be employed as indicators. For example, Savage (2009) and Barr et al. (2013) demonstrate how the tissue-$\delta^{15}N$ and tissue-N values of *Ulva* can be used to indicate anthropogenic nutrient loading in New Zealand estuaries after factoring out natural cues. This consideration around nutrient dynamics is being further explored through the estuarine health programme.	None Needed Currently being addressed by ECG

B10	Wriggle	Clarify relationships between sediment characteristics and macroinvertebrates.	Townsend & Lohrer (2015) (p21) Cornelisen & Gillespie (2015)	A strong component of the ECG is the quantitative identification of relationships between critical abiotic factors and macroinvertebrates in representative estuary habitat (supported by Ben Robertson PhD research). It is noted that the use of sediment macrofauna as an integrated indicator of sediment condition is probably the most widely accepted and applied method of evaluating ecological condition. It is used in a vast number of indices, and is a fundamental part of most marine and estuarine monitoring programmes. As Cawthron extensively promote its use and application, their concern with its use in the ECG is unclear. It is also worth noting that not all systems in NZ have the same issues, e.g. Auckland estuary dataset is often referred to and metals being the primary stressor. This situation is not applicable to Southland i.e. different issues are prevalent.	None Needed Currently being addressed by ECG and EHP
B11	Wriggle	Sediment nutrient measures are indicative of processes happening at a site scale, but do not necessarily reflect current water quality conditions and do not necessarily drive macroalgal growth (which is influenced by both water-column nutrients and nutrients that are released from sediments).	Townsend & Lohrer (2015) (p23)	Agree. Macroalgal growth is influenced by both water-column nutrients and nutrients that are released from sediments. However, the ECG approach does not rely on sediment nutrients to produce the nutrient load - ecological response gradient. It will be statistically tested in regard to the extent that it covaries with other potential responses to N load e.g. TOC, TS, redox potential, macroalgal cover.	None Needed Currently being addressed by ECG
B12	Wriggle	There is no assessment of how accurately observers can demarcate different habitat types or the variability between observers. This can be termed "repeatability". There needs to careful documentation of methods for: • Substrate maps	Townsend & Lohrer (2015) (p13)	The ECG proposal details a range of specific components where finer scale assessment is proposed. For example, it is recommended that broad scale mapping be extended to include transect-based delineation of boundaries between gross eutrophic zones and surrounding habitat. Targeted measurement of grain size and redox potential will be used with substrate and macroalgal indicators to characterise the transition in sediment condition	None Needed Currently being addressed by ECG

		• Macroalage and broad scale maps • Fine scale sampling Variability can occur at a finer scale than is denoted on broadscale maps.		around gross eutrophic zones, as well as across representative parts of dominant substrate/habitat zones	
B13	ES & Wriggle	Community (taxa) changes are not appropriately or accurately linked to environmental variables. For example, in 2013, the low abundance and diversity of fauna at Waikawa Sites A and B is attributed to low mud content (2.7-6.3%). This is speculative and not supported by other data (e.g., mud content of 1.1-5.3% in 2006 at the same sites was associated with diverse and abundant communities). While other data from a range of Auckland areas sites suggests that mud content <2% can have low species richness, richness is generally at near its maximum in the 2.7-6.3% mud content range (Rodil et al. 2013). It is also recommended that less reliance is placed on AMBI type indices that are not validated for the indicators or areas of use. Lack of validation of several indices used (e.g.WEBI, simplistically	Townsend & Lohrer (2015) (p4,16,17,36) Jenkins (2013) (p9)	A strong component of the ECG is the quantitative identification of relationships between critical abiotic factors and macroinvertebrates in representative estuary habitat (supported by Ben Robertson PhD research). It is noted that the use of sediment macrofauna as an integrated indicator of sediment condition is probably the most widely accepted and applied method of evaluating ecological condition. It is used in a vast number of indices, and is a fundamental part of most marine and estuarine monitoring programmes. It is worth noting that not all systems in NZ have the same issues, e.g. Auckland estuary dataset is often referred to and metals being the primary stressor. This situation is not applicable to Southland i.e. different issues are prevalent. The data sets being used within these ‘indices’ are different and represent different estuaries both climatically and by stressor type. The data set used in Rodil et al. (2013) paper exclusively used Auckland data to develop the traits based index (TBI). This has not been tested for estuaries beyond Auckland and its applicability and reliability needs to be demonstrated. The Rodil et al. (2013) paper supports a locally developed traits based approach to	None Needed Currently being addressed by EHP

		adapted from a single overseas AMBI formulation) to indicate estuarine health.		indices. The same reasoning should be applied to within NZ (which experiences different situations) not just on an international scale as discussed in the paper. A more suitable index, using the appropriate data set for Southland, is being developed as part of supporting work to the EHP. The key research questions here are : • Is the index developed using Auckland data appropriate for application across other estuary location in NZ? • Can an index be developed for NZ which incorporates all of the NZ data (not just Auckland)? However this sits squarely outside of the EHP (which is concerned with Southland) and is more appropriate to be addressed by CRIs and universities within NZ.	
B16	ES	Site C in the Pourakino Arm, is less reflective of the wider estuary and has issues with homogeneity across the monitored area. However, the lack of uniformity at site C is likely linked to the hydrodynamics and mobile sediments. For consistency in the data, it is not recommended that site is moved. However in the future when sampling is conducted, it is suggested that the degree of	Townsend & Lohrer (2015) (p26)	Currently the monitoring of estuaries was discontinued in Southland in 2013. Should it resume then these recommendations should be considered.	None Needed

		intrusion of the sandbar is noted. Records could be kept of the position of sampled cores in relation to this intrusion (i.e. which samples come from the sandbar, next to it, away from it, etc.) as this could allow a more structured data analysis. If the intrusion increases, the suitability of the site would need to be re-evaluated. As with other Estuaries in the Southland Region, the value of intensively sampling eutrophic sites may be relatively low; resources could perhaps be reallocated to improve the temporal frequency of existing fine-scale monitoring.			
B17	ES	Fortrose – Consideration should be given to the establishment of sediment accumulation plates and a quantitative measurement of sediment properties at this location. This will reduce the arbitrative/anecdotal assessment of increasing muddiness.	Townsend & Lohrer (2015) (p27)	Currently the monitoring of estuaries was discontinued in Southland in 2013. Should it resume then these recommendations should be considered.	None Needed

B18	ES & Wriggle	We recommend that notes or photos documenting degree of difference across the site are collected on each visit to help in the interpretation of the data.	Townsend & Lohrer (2015) (p27)	Currently the monitoring of estuaries was discontinued in Southland in 2013. Should it resume then these recommendations should be considered.	None Needed
B19	ES & Wriggle	Unsupported and untested statements and the interpretation of data. There are multiple instances in the reports where statements are not supported by the available data. For example, In Robertson and Stevens (2013A) they discuss the greater number of species living atop the sediment at eutrophic sites, compared with those living and feeding within the sediment column. In their interpretation they state.	Townsend & Lohrer (2015) (p37)	Further clarity will be provided in the ECG and EHP work.	None Needed Currently being addressed by ECG

Appendix 2 – Review response from Wriggle Coastal Management Ltd

Wriggle Coastal Management Ltd have been contracted by Environment Southland for several years to conduct monitoring and investigations around Southland Estuaries for several years.

Specific Comments on:

‘A Review of the Ecological Health and Water Quality in four Southland Estuaries

Prepared April 2015 for Environment Southland and Dairy NZ

by Michael Townsend and Drew Lohrer (NIWA)’

The NIWA review is primarily a Dairy NZ commissioned critique of the methods, analyses and interpretations of data collected in Southland estuaries over a number of years by Wriggle Coastal Management as part of the broader Environment Southland coastal monitoring programme. It follows (and largely duplicates) an Environment Southland commissioned external peer review undertaken by the University of Melbourne (Jenkins 2013), but takes no account of changes made in response to that review.

The NIWA review falls into two main areas:

i. an appraisal as to whether the monitoring reports correctly identify the primary issues in the estuaries monitored with regard to sediment and eutrophication related impacts, and

ii. detailed comment on the methods, analysis and reporting of results.

Feedback is provided below firstly in relation to the overall conclusion and recommendations, and secondly on relevant aspects of detail raised in the review.

Overall Conclusions (page 38)

“……Although we have concerns with various methods, analyses, and interpretations of the data—and the lack of underpinning information to support of indices and bandings—the authors of the Southland Estuaries monitoring reports have collected a variety of useful information over a number of years from the four estuaries we examined. Importantly, by and large, the authors have correctly assessed the key issues affecting the four estuaries. They have been able to identify significant degradative changes over time, and have generally ranked the estuaries accurately in terms of their degree of healthiness. Essentially, we agree with Jenkins (2013) that the comprehensive range of measured indicators of the physical, chemical and biological condition provides a solid platform of information that is able to demonstrate the stark contrast between healthy and unhealthy sections of estuaries. There is overwhelming evidence to support significant anthropogenically generated eutrophication and sedimentation in the upper regions of New River and Jacobs River Estuary. Furthermore, although strong statistical trends may be absent for individual variables, the

weight of evidence from multiple measured parameters indicates continued undesirable changes for New River, Jacobs River and Fortrose Estuaries……"

Response: Overall the reviewers conclude that the monitoring undertaken by Wriggle:

- correctly assessed the key issues effecting the Southland estuaries reviewed,
- identified significant degradative changes over time,
- accurately ranked estuaries in terms of health,
- provided overwhelming evidence to support the presence of significant anthropogenically generated eutrophication and sedimentation

These conclusions provide a very strong endorsement of the Environment Southland estuary monitoring programme. The vast majority of the concerns raised in relation to the various methods, analyses, and interpretations of the data are attributable to the prioritisation of available resourcing towards the cost-effective detection of key issues, which has been successfully achieved.

The concerns raised in the current review also fail to consider the substantial additional work undertaken since 2013, which address the bulk of the issues raised. Consequently the vast majority of the largely minor concerns raised have already been addressed or can be very simply addressed through additional resourcing. The proposed Southland ECG and the national Estuary Trophic Index (ETI) (in draft form at present) currently under development by NIWA and Wriggle, will provide further resolution of issues in relation to national consistency and validation condition indices and bandings.

It is noted that concerns relating to the lack of underpinning information to support indices and bandings appear to overlook the context in which they were developed - a suite of screening-level tools developed by Wriggle, on the fly and without funding, to help guide the assessment of individual estuary condition. They have been applied, with a range of caveats, to Southland's estuaries because NZ's government funded research providers have yet to provide regional councils with any meaningful national guidance on estuary assessment and management. It is both obvious, and explicitly stated, that further development and validation of the interim bands are needed, and the recommended response to the identification of the significant issues identified in Southland was to do precisely do that. That is the basis for the proposed ECG.

Overall Recommendations (page 38)

Five recommendations were made in the review:

Recommendation 1. *Mine existing data, focusing on what we believe are the two most important and indicative data sets, namely, macroinvertebrate community data (fine scale), and 'nuisance' macroalgae cover data (broad scale). This may involve checks on the taxonomic resolution and quality of the macroinvertebrate data, and/or recalculation of the macroalgal coverage statistics from raw images.*

Response: Agree, in part. It is clear that this would be valuable and has yet to be undertaken in a comprehensive manner for Environment Southland. This is proposed for inclusion in the ECG. However, the inclusion of mud as a key driver of estuary ecological condition also needs to be in the main focus, and is therefore proposed for inclusion in the ECG.

Recommendation 2. *Explore alternate macroinvertebrate sampling strategies to maximise their fitness-for-purpose moving forward. For example, it may be beneficial to cease macroinvertebrate monitoring at 'grossly* *eutrophic' sites (where rapid changes for better or worse are unlikely, and where general site conditions can be tracked with photos), and instead increase temporal resolution at the other fine-scale macroinvertebrate monitoring sites.*

Response: Disagree. A more rigorous approach based on sound risk assessment principles is proposed as part of the ECG (see Comment 3 below).

Recommendation 3. *Conduct a comprehensive analysis of existing macroinvertebrate datasets, focusing on (i) changes in macrofaunal community composition over time, (ii) temporal trends in selected individual taxa, (iii) changes in site-specific environmental data and modelled/measured catchment loading information. There are a variety of advanced univariate and multivariate statistical modelling techniques that can be utilized to test for the existence of temporal trends and to analyse stress-response relationships while accounting for natural temporal cycles.*

Response: Agree; such a recommendation is addressed in the proposed ECG.

Recommendation 4. *Conduct a comprehensive analysis of patterns of nuisance macroalgae coverage in estuaries, with a focus on (i) trends over time and how they correlate with trends in modelled/measured contaminant loadings from the catchment, (ii) an examination of the role of internal estuarine hydrodynamics, and degree of match between water circulation patterns and the spatial distribution of macroalgae within estuaries, and (iii) other contributing factors such as benthic habitat/substrate types, interactions between turbidity and nutrients, etc.*

Response: Agree; such a recommendation is addressed in the proposed ECG.

Recommendation 5. *Quality assurance / quality control procedures are needed throughout the programme, including better standardisation of field methods, macroinvertebrate identification checks (e.g., 10% of samples; Hewitt et al. 2015), and regular critical review of technical reports. Independent reviewing of reports could be done at minimal cost via a number of different avenues, for example, reciprocal relationships with Regional Councils or small contracts to experts identified by the Coastal-SIG.*

Response: Agree; Wriggle already use QAQC procedures equivalent to those very recently proposed for the first time in NZ to standardise sample collection and analysis (Hewitt et al. 2015).
Reviewing of reports is currently undertaken by Environment Southland specialist staff who contract external reviewers as considered necessary (e.g. Jenkins 2013). Further, wider review on generic programme and reporting components is provided by other Councils as part of their review processes (GWRC, NCC, TDC, MDC) either internally, or through contracted review by research providers (NIWA, Cawthron, Landcare), or other consultants.

Recommendation Conclusion. *If these recommendations are acted upon, and if our criticisms of existing monitoring methodologies and reporting are addressed, we believe that the Environmental Southland monitoring data can be used to generate scientifically defensible conclusions regarding the role of catchment activities on estuarine health and firmer links between dairy-associated nitrogen loading and the degradation of estuarine receiving bodies.*

Response: Agree.

Key statements from the Executive Summary and Report

Key statements presented in the Executive Summary and Report by the reviewer are commented on below. Additional comments on more detailed aspects of the review follow this section.

1. Fine Scale Design.

***Variables or Indicators**: The fine-scale variables that have been assessed in Southland estuaries are appropriate, and are comparable to those that are routinely measured in estuaries throughout New Zealand for state-of-the-environment reporting.*

Comment 1: Agree, but the reviewer fails to report on more recent fine scale estuary monitoring advancements by Wriggle, that are designed to better assess differences in eutrophication related variables with depth and therefore provide a more accurate assessment of environmental conditions within the 15cm deep core used to assess the macroinvertebrate community. These advancements have been included in the fine scale component of the proposed ECG put forward by Wriggle. They include addition of the following indicators: total sulphur and redox potential (measured with a meter throughout the sediment profile), as well as trialing more novel bacterial enzymatic indicators.

2. Statistical Interpretation.

However, interpreting temporal trends and evaluating the significance of differences between sites was often difficult due to a poor characterisation of data variability. This compromises the appropriate allocation of sites into particular environmental bands (poor, moderate, healthy).

Comment 2: Agree. However, the reviewer failed to provide the background to the absence of statistical analysis from the reports. Environment Southland decided early on in the estuary monitoring to proceed with a programme that was primarily data only, supported by screening level observations in relation to data analysis, and that they, or a contracted provider, would undertake detailed statistical analyses to support any preliminary screening level observations (at approximately 5 yearly intervals, i.e. SOE reporting periods) made on the data in the annual reports. A consequence of this lack of full statistical analysis is that conclusions (while valid and endorsed by the reviewer) were sometimes not as strongly supported as they could have been.

Since late 2013, Wriggle have routinely undertaken full statistical analysis of all fine scale monitoring of estuaries they undertake throughout NZ in order to minimise the risk of confusion regarding whether or not statistical analyses are being provided. In all cases, raw data and analytical results (lab originals) are appended to each report to allow error estimates to be derived or full statistical analyses to be undertaken.

To rectify this problem for the proposed ECG, a full statistical analysis of the available relevant ES fine scale estuary monitoring data is required before it is used in the ECG analysis. In particular, statistically addressing the differences between sites chosen to represent the ECG (and less importantly) temporal trends at each site are required. This has not currently been adequately addressed in the current ECG proposal and therefore it is recommended that an additional task be added to the proposal to cover it.

Statistical analyses in Wriggle fine scale reports (e.g. see GWRC Porirua Harbor Fine scale report 2015) now include:

- Variance of each variable.
- Regression analysis (e.g., ordinary least squares regression) for trends in biotic and abiotic variables between baseline (usually 3-4 yrs of consecutive data) and subsequent impact years (usually at 5 yearly intervals).
- PCO Ordination plots to enable an initial visual overview (in 2-dimensions) of the spatial and temporal structure of the macroinvertebrate community.
- The BIO-ENV program in the PRIMER (v.6) package is used to evaluate and compare the relative importance of different environmental factors and their influence on the identified macrobenthic communities.
- Assessment of univariate indices such as species richness, abundance, diversity and major infauna groups.
- Assessment of the response of the macroinvertebrate community to increasing mud and organic matter based on identified tolerance thresholds for NZ taxa (e.g. WEBI Index using data in Robertson et al. 2015).
- Assessment of changes to individual species response using SIMPER analysis (PRIMER).
- In addition, inter-annual sampling is proposed for the ECG for key environmental parameters, to address interannual variation.

3. Site Selection.

The reviewer is in general agreement that the sites reflect the condition of both low and high susceptibility zones in each estuary, but raises one main recommendation in this regard as follows:

Recommendation 2. *Explore alternate macroinvertebrate sampling strategies to maximise their fitness-for-purpose moving forward. For example, it may be beneficial to cease macroinvertebrate monitoring at 'grossly eutrophic' sites (where rapid changes for better or worse are unlikely, and where general site conditions can be tracked with photos), and instead increase temporal resolution at the other fine-scale macroinvertebrate monitoring sites.*

Comment 3: The reviewer recommendation to cease macroinvertebrate monitoring of gross eutrophic sites and increase the temporal resolution at the low susceptibility sites, is contrary to fundamental risk assessment approaches, i.e. to identify and focus monitoring in the areas where change is most likely to occur in response to target stressors, and to minimise monitoring in low susceptibility zones where change is less likely. In shallow intertidal dominated estuaries, the main basin sites are located in low susceptibility zones where it is unlikely that any significant response to nutrient and sediment loads will occur (i.e. they are very well flushed and therefore limited by physical factors rather than nutrient and sediment loads). It also ignores the fact that the macroinvertebrates are the key ecological components of the monitoring programme and therefore the whole weight of evidence in terms of nutrient load/sediment abiotic condition/ecological response rests on them. To cease monitoring at such sites will directly compromise the ability to derive validated guidance on estuarine condition and establish management thresholds/targets (a critique made by the reviewers of the current programme).

The proposed ECG recommends improving resolution within sediments at <u>both</u> low and high susceptibility sites.

4. Variation in the total area used in broad scale habitat mapping, which compromised spatial summary statistics.

Comment 4: Agree, there are variations in the total area of each estuary over the years in some instances. These have arisen primarily as mapping of several of the estuaries (Fortrose, New River and Jacobs River) was undertaken during development of the National Estuary Monitoring Protocol when techniques were still being trialled and developed, and because more recent aerial photograph coverage and quality has enabled better discrimination of habitat boundaries. Because the broad scale features are used as a screening tool, supported by interim ratings, to highlight significant changes in the estuary, minor differences in area are less important than the detection of specific issues and change. The reporting seeks to highlight, in summary form, the key habitat features in the estuary, and the nature and extent of major changes over time. In most instances this is shown directly on summary maps, supported by written narative. The GIS layers provided to the Council are intended for the exploration of changes at a high level of spatial detail. Where key stressor related issues are identified, more detailed studies or targeted investigations are recommended. It is also important to note in this regard that the use of summary statistics alone can easily mask important changes – i.e. if 2ha of seagrass is lost in one area but 2ha grows in another, there is no change evident in the summary statistics, but a significant change in the estuary may be occurring. Consequently, the narrative in the reports is used to identify and highlight such changes, and importance is placed on using the best mapping information available, even if it results in changes to overall estuary area as a consequence of improved mapping resolution.

5. Inconsistent and problematic methodologies used for assessing sedimentation accumulation rates.

Comment 5: Disagree - The reviewers have incorrectly assumed how sediment plate data are measured in reaching this conclusion. To avoid the obvious issues postulated by the reviewer, the following measures have been used since the programme was established: A 2.5m straight edge is laid across each plate and settled to reflect the average sediment level across the site. This evens out small scale surface irregularities and completely avoids the issue of localised scouring above the plate (e.g. from macroalgae that may get caught on marker posts). Mulitiple measures are then made of the depth to the underlying plate to account for possible variance in the level of the plate. The straight edge is then relaid and measurements are repeated (3 measures made per site). Because of the high level of repeatability of these within plate measures, all measures are averaged in the field and a single plate measure reported. Measured depths are also able to be cross checked by measuring average surface sediment levels compared to marker posts installed at each site (each driven in to a measured height above the sediment surface). In addition, to check for potential subsurface plate movement (which has never been detected) the straight edge is placed on top of the marker post and the depth to the buried plate measured and compared to the baseline measure. The ECG proposes the installation of custom designed screw anchored plates without surface marker posts (relocated by GPS and metal detector). The approaches described above have consistently measured sediment levels to a high level of accuracy from a range of estuary types thoughout NZ. The method is is recognised/applied internationally, and has been validated extensively throughout NZ by many councils, and was initiated in Southland following initial method development by NIWA and Waikato Regional Council.

6. Lack of validation of the values used to define the 'bands' of estuarine health conditions (including indices).

Comment 6: Agree. NZ estuarine research, funded through long term government funded programmes over past decades, has yet to produce comprehensive tools to enable Councils to evaluate and integrate estuary monitoring results. To assist Environment Southland in this regard, interim condition ratings ('bands') were developed "on the fly" by Wriggle without funding as a screening tool to help Council interpretation of results.

Limitations in the development of the condition ratings have been specified (as noted by the reviewer) e.g. "the guidelines proposed require further development and refinement but are intended as the first phase…at present many of the specific criteria for rating estuaries using the specific indicators (e.g. very good, good, fair and poor) are preliminary or as yet undeveloped".

Since 2013 (i.e. following the Jenkins (2013) review) additional validation has been undertaken for many of the proposed ratings. This validation is reported on in more recent monitoring reports, or has been included in the national Estuary Trophic Index (ETI) currently being developed by NIWA and Wriggle. This has not been considerered by the reviewer.

Compilation and collection of data from a range of estuary types throughout NZ is a core part of the ETI currently being prepared by NIWA and Wriggle, and is included throughout the ECG proposal. Both will provide more comprehensive data to support, validate and refine proposed ratings.

Further, it is emphasised in the monitoring reports that the interim ratings (based on available estuary monitoring data, guideline criteria, and expert opinion) are designed to be used as a screening tool in combination with each other, usually involving expert input, when evaluating overall estuary condition and deciding on appropriate management. In other words, the ratings are applied as part of a suite of indicators that are considered in combination by an expert, when determining overall condition, and deciding on monitoring and management priorities. The response when issues are identified by the screening tool is to trigger targeted monitoring relevant to the problem conditions identified, and to undertake further assessment of issues to consider what specific response or management actions are appropriate e.g. the proposed ECG.

It is also noted that, based on the 2012 monitoring results, targeted investigations were recommended in relation to assessment of the key sediment and nutrient drivers impacting on New River Estuary. Wriggle were subsequently contracted by Environment Southland to undertake a programme of work in 2013 (e.g. derive sediment and nutrient load limits for New River Estuary) to support and guide the Council in making management decisions. This work was terminated, without explanation, by Environment Southland before completion.

7. Multiple issues relating to variance, bandings, indices and their interaction

a) *…. one of the major weaknesses of the current estuarine assessments occurring in Southland area estuaries is a poor characterisation of variance, which means that fit of data into particular environmental bands*

Comment 7a: Means and ranges are now plotted for most variables (e.g. metals, TOC, TP, TN RPD, and sediment rate measures). The exception has been where stacked bar plots are used for sediment grain size, and for macrofauna data (to emphasise taxonomic groupings or where biotic indices do not allow it). Summary tables can be amended to error estimates for grain size. In addition, raw data are appended in each report, and spreadsheets of data provided, to allow error estimates to be derived. These changes, implemented following the 2013 review, have not been considered by the reviewer.

b) *Accuracy of broad-scale mapping techniques is not fully addressed in either monitoring reports or the EMP (Robertson et al. 2002; Part A page 36). Specifically, details on the use, repeatability and accuracy of ground-truthing information is absent; this was noted by Jenkins (2013).*

Comment 7b 1: The National Estuary Monitoring Protocol (NEMP) describes methods for broad scale mapping and habitat classification of dominant features. The methodology focuses on a comprehensive spatial coverage, with the whole of the estuary walked and assessed to define spatial features and boundaries, including collection of extensive geo-referenced photos, and georeferenced field notes. Emphasis is placed on defining boundaries between habitats, with experienced ecologists commonly mapping across multiple days and tidal cycles (dependent on estuary size and complexity). Groundtruthed features clearly distinguishable on aerial photos (e.g. saltmarsh, rockfields, cobble beds) are digitised to 1-5m accuracy (depending on the quality of aerial photos available). Features not clearly visible on aerial photos (e.g. soft mud/firm muddy sand boundaries, low density seagrass beds) are mapped in the field using a combination of laminated aerial photos, electronic maps with live GPS tracking (e.g. ipads), supported by georeferenced photos. Boundaries between sand and mud substrate types commonly sit along a gradient, albeit with often sharp transitions from one to another. Where obtaining highly accurate spatial boundaries is a priority, additional transect based sampling and sediment grain size analysis is recommended (as proposed as part of the ECG).

Checking of mapping accuracy and repeatability is commonly undertaken in two ways. Observers routinely independently map the same area, and compare results to ensure classification consistency. After mapping is completed, Council staff nominate an area for validation and revisit the estuary with field and/or electronic maps with live GPS tracking (e.g. ipads) used to validate the accuracy of mapped features. Council staff commonly assist in mapping and gain a first hand appreciation of groundtruthing.

Since 2013, appended maps showing groundtruthing tracks have been provided to indicate general groundtruthing coverages. Logging of location-specific individual ground-truthing points has been proposed previously (Jenkins 2013) and would greatly increase costs without improving mapping accuracy (see also following comments).

Comment 7b 2: Broad scale habitat mapping is designed as a screening tool, that measures a number of broad scale screening level indicators, for assessing the potential presence of estuary issues in relation to sedimentation, eutrophication, and habitat loss. If the results of the screening level assessment shows potential for an issue, then this triggers a more detailed targetted investigation. The broad scale screening level indicators are therefore designed as low-cost, semi quantitative tools that, if necessary, can be augmented by more detailed approaches if a potential problem is identified. For example,

- The potential issue of broad scale muddiness is measured by the indicators 'soft mud' and 'very soft mud' which are distinguished by sinking depth (the former "when you'll sink 2-5 cm" and the latter "when walking you'll sink >5cm"; Stevens and Robertson (2009)). Note that recent Wriggle estuary monitoring reports include an assessment of the measured mud content within soft mud and very soft mud categories throughout a range of estuaries that indicate "soft muds" generally fit the category of >25% sediment mud content. Once issues of increasing soft mud and very soft mud have been identified in estuaries, the appropriate response is to trigger a more detailed evaluation that is likely to involve more rigorous monitoring of the muddy areas to more accurately determine their boundaries and their mud content. Note, to accurately map the unvegetated component an estuary (e.g. New River) for mud content (particle grain size analysis) at one sample every 2500m2 (one sample every 50m) would equate to 12,000 samples at $100 each, or a total analysis cost of approximately $1,200,000 (exclusive of sample collection and reporting). To accurately map just the soft and very soft mud areas in New River (669ha in total) at one sample every 2500m2 would equate to 2,676 samples at $100 each, or a total analysis cost of approximately $267,600. As a compromise, the proposed ECG includes a proposal to measure grain size along representative transects through the main zones of soft and very soft muds in each of the 4 target estuaries.

- The potential issue of broad scale nuisance macroalgal growth is measured by the indicators: macroalgal cover (in the past) and since 2013 (macroalgal cover, macroalgal biomass and % entrainment) using the UK Opportunistic Macroalgal Blooming Tool (WFD-UKTAG, 2014). This approach measures these indicators within representative patches using quadrat approaches, enabling estimates of variation to be derived. The integrated index provides a comprehensive measure of the combined influence of macroalgal growth and distribution in an estuary and is the approach proposed in the ECG.

WFD-UKTAG (Water Framework Directive – United Kingdom Technical Advisory Group). (2014). UKTAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool. Retrieved from http://www.wfduk.org/sites/default/files/Media/Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG Method Statement.PDF.

c) ***Condition rating - banding*** *The type of information, or lack thereof, used to develop condition ratings should be reported for each individual variable in the methods of the report.*

Comment 7c: See Response 6 above.

d) *Confidence in the condition rating bandings is related to a demonstration of their validity, i.e., studies that specifically test them. Primary literature demonstrating statistical testing or evidence of validity should be cited.*

Comment 7d: See Comment 6 above.

e) *The reliability and veracity of the bandings is a key consideration when evaluating the data and the conclusions made from the results (i.e., how confident are we that 'poor' is 'poor'?).*

Comment 7e: Agree.

f) ***Indices.*** *Evidence has not been provided or cited that explores the validity of the indices used on Environment Southland estuarine data.*

Comment 7f. Macrofauna - There has been no specific validation undertaken of the AMBI formula used, recognising its widespread use and validation from throughout the world. Limitations with the index are well known (e.g. it does not account well for individual species variance, and relies on relevant sensitivity data for local species from representative habitat). Consequently, Wriggle emphasise a multi-criteria approach be used when assessing sediment macrofauna, as supported internationally (e.g. Borja et al. 2012 concluded that no single biotic index can correctly assess the estuary condition). It is recommended that physical and chemical indicators of NZ estuary condition (e.g. TOC, TN, redox/RPD, grain size, heavy metals), mud/organic enrichment sensitivity ratings for NZ estuary taxa (e.g. the modified AMBI or WEBI), and changes in abundance of individual species, preferably in relation to their sensitivity to relevant stressors, e.g. the 5 major mud/enrichment tolerance groupings (i.e. "very sensitive to organic enrichment" group through to "1st-order opportunistic species" group) **<u>all</u>** be used in the assessment of macrofauna.

To adapt the AMBI for NZ use, and ensure appropriate sensitivity data for NZ species are applied, Wriggle have put significant effort into validating the sensitivity of NZ species to both mud and organic enrichment from representative NZ estuary habitats (dominated by largely intertidal, well-flushed, shallow, short residence time estuary types and the absence of midwater saltmarsh, i.e. different from the physical conditions which have been used to derive many international biotic indices). The output has been the "Wriggle Estuary Benthic Index" (WEBI) with validated sensitivity ratings from a variety of estuary types spread throughout NZ (e.g. Robertson et al. 2015, Robertson and Gardner. 2015 in press), and with on-going development proceeding through PhD study funded by Wriggle and Environment Southland. This work has not been considered by the reviewer.

Further, criticism by the reviewer of the failure to apply species sensitivity levels to some taxa (e.g. amphipods) is disingenuous and overlooks the both the extreme difficulty and limited capacity in NZ to identify this group to species level, and the absence of NZ species-specific sensitivity data for the group. It is also noted that the proposed QAQC analysis (Hewitt et al. 2015) fails to address the issue of the degree of taxonomic resolution and the species sensitivities necessary to address specific stressors in NZ estuaries.

It is further noted that biotic indices developed over many years in NZ (e.g. AC/NIWA BHM and TBI models), and which are often promoted as being more appropriate for NZ use than the AMBI (or the NZ adaptation - the WEBI), have significant limitations with respect to their development within a narrow range of estuary types from a restricted geographical region, across a narrow gradient of estuary conditions (predominantly sites with low eutrophication pressure), and target specific stressors e.g. heavy metals or mud. Consequently, their application to estuaries with significant eutrophication symptoms such as those in Southland is untested.

Seagrass - Seagrass is mapped to spatially document location and to record density. As the ecological value of high density (e.g. >50% cover) seagrass beds is assumed to be greater than low density (e.g. 1-5% cover) beds, a multiplier was previously applied to weight seagrass changes based on density (loss of a high density bed considered to be more significant than loss of a sparsely covered bed). To date the basic mathematical multiplier which produces a single integrated numerical metric for all seagrass cover, has been placed within bands that nominally reflect observed conditions in Southland estuaries (from very good to poor). It is currently only applied within an estuary to identify whether significant changes are present, and requires further development. While the reviewer recommends it be done, all data are already presented as Ha (split within nominal % cover bands), and all raw data are provided to the Council as GIS layers for subsequent analysis. For seagrass in particular, the purpose is to simply enable changes within an estuary to be reliably tracked over time and the metric applied is considered suitable for this purpose.

Macroalgae - Macroalgal assessment currently uses a modified 5 part multimetric index Opportunistic Macroalgal Blooming Tool (OMBT) methodology developed by the Water Framework Directive – United Kingdom Technical Advisory Group (2014). The OMBT produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and which is placed within overall quality status threshold bands (i.e. bad, poor, good, moderate, high) to rate macroalgal condition (Table 2). This integrated index provides a comprehensive measure of the combined influence of macroalgal growth and distribution in the estuary. This is proposed for use as part of the ECG but has not been considered by the reviewer.

g) *In summary, the information on the indices does not demonstrate that they are well explored for their validity and appropriatenes.*

- *It is good scientific practice, and the responsibility of an investigator to demonstrate or cite the validity of metrics and banding before they are used. A suitable pathway may include an initial study that tests an index, followed by refinement over time, followed by publication of the information in peer-reviewed scientific papers, before eventual implementation in SOE reporting. This has been the case for the health indicators currently being used in Auckland and Waikato Regional Councils (Benthic Health Models for heavy metal contaminants and sediment mud content, Anderson et al. 2006, Hewitt and Ellis 2010, Hewitt et al. 2012, http://stateofauckland.aucklandcouncil.govt.nz/marine-report-card/upper-waitemata-harbour-reporting-area-2014/; Traits Based Index (TBI) that is sensitive to mud and metals, van Houte-Howes and Lohrer 2010, Lohrer and Rodil 2011, Rodil et al. 2013).*
- *Where categorisation of a metric into bands is being trialled, an investigator has the responsibility to clearly state where bandings are associated with expert judgment, or where ongoing testing is necessary.*
- *In agreement with Jenkins (2013), it is recommended that less reliance is placed on AMBI type indices that are not validated (particularly non macro-invertebrate usage).*

Comment 7g: Agree.

8. Water Quality

The reviewer includes a section on water quality, a component that is not included in previous monitoring undertaken by Wriggle. The following comments are made:

The reviewer states that: In Southland, estuarine water quality is not measured but is inferred from i.) macroalgal coverage (% cover & density), ii.) sediment nutrients (TOC, TN & TP), and iii.) nutrient loading models, specifically, CLUES model predictions.

Comment 8: Agree; However, the reviewer provides very confusing information and recommendations in this regard. For example they state that it is notoriously difficult to assess an estuaries condition using water quality for various reasons as follows:

It is relatively simple to measure the concentrations of solutes and solids that are suspended in estuarine waters (there are standard sampling protocols and analytical methods). However, using this information to assess 'water quality' in estuaries is notoriously difficult, because of the high variability in water quality parameters associated with tidal and freshwater flow variation. Moreover, uptake of nutrients by plants can confound the interpretation of nutrient concentration data; an estuary with high rates of nitrate loading may have relatively low concentrations of nitrate in the main water body if the loaded nitrate has been taken up and incorporated into plant biomass. Thus, in theory, an estuary with many of the symptoms of eutrophication may have lower than expected dissolved inorganic nutrient concentrations.

They also indicate *that "Estuarine water quality monitoring is conducted elsewhere in New Zealand (e.g., Walker and Vaughan 2013), as a component of an integrated monitoring framework"*, yet they:

- Fail to identify any relationship between the Auckland estuary water quality sampling and trophic/sedimentation ecological response, and therefore demonstrate its usefulness to the ES programme
- Ignore the obvious proviso that for some estuaries of a certain typology, water quality monitoring is approriate and highly refective of estuary condition (e.g. deeper coastal embayments and fiords), wheras for shallow estuarine systems that dominate NZ estuary types (and shallow lakes for that matter), the sediments are the primary indicator of estuary condition.

The reviewer then makes the statement that: *"If Environment Southland is to move towards limit setting of nutrient inputs and the identification and management of nutrient sources, it likely that a comprehensive monitoring programme will be required to:*

a.) monitor the nutrient status moving forward

b.) to refine and validate model predictions,

c.) evaluate and report compliance and identify non-compliance.

This statement ignores the lack of any proven relationship both internationally and nationally between water quality and trophic and or sedimentation state for shallow intertidal dominated estuaries (i.e. NZ's dominant estuary type). The only reason to monitor would be to see if a relationship could be established for ES estuaries and if a numerical model was to be developed then the concentrations would provide useful validation for the water quality component of the model (alongside the much more useful sediment monitoring data, including denitrification measures).

Currently, the proposed ETI will include a preliminary review of the available ICC estuary monioring data collected at multiple sites annually since the early 1990s, to gauge its potential usefulness and help make informed recommendations for the need for future water quality monitoring data.

9. General Methodological Problems Raised by the Reviewer.

1. ***Details on the processing/drying of heavy metal samples seems to be missing?***

   Response: The analytical methods are all specified in the Hill Laboratories protocols, summary appended in each report, and all original data held by Environment Southland.

2. ***Salinity and grain size – how are they measured.***

   Response: Salinity measured using salinity electrode and meter in field in pools of water left at low water at the site. Grain size analysed by the specified Hill Laboratories methods, summary appended in each report, and all original data held by Environment Southland.

3. ***Use of the term Redox Discontinuity Potential (RDP), when in fact aRDP was measured. RDP depth is based on an electrical potential difference and thus requires an electronic sediment probe. The method of visual assessment that was used should be referred to as the Apparent Redox Discontinuity Potential depth, or aRDP (see Gerwing et al. 2013 and references therein).***

   Response: Agree. See Response 1 above that, within the Wriggle monitoring protocol and therefore in the ECG proposal, aRPD is now supported by RPD measured with a millivolt meter throughout the sediment profile. Also note that the review authors have mis-labelled the RPD layer (called the redox potential discontinuity layer (e.g. see Gerwing et al. 2013) by calling it the RDP layer.

4. ***Variation in the total area used in broad scale habitat mapping, which compromised spatial summary statistics.***

   Response: See Comment 4 above. Minor issues in standardisation of reporting are noted and will be addressed. Overall, the reviewers present detailed comments on broad scale habitat changes in New River Estuary that emphasise minor issues and overlook the screening purpose of the broad scale measures applied. For example, their detailed re-analysis showed:

   ….with standardisation, there is a more modest increase in mud of 1.8% (moving from 20.9% to 22.7% between 2001 and 2012)…..

   However the reviewers recalculation of mud area from 20.9% to 22.7% between 2001 and 2012) – (i.e. tweaking the accuracy of a screening measure by 1.8%) is inconsequential when the issue is that soft mud has increased hugely (by over 20%) from 2001 to 2012. The broad scale reporting highlights this key finding, and provides the Council with the highly detailed GIS data to enable them to undertake whatever specific analysis and reporting requirements they require to further explore and address this change.

   It is also noted that in most instances the detailed questions raised by the reviewer are either already addressed in report narratives, or readily answered through comparison of the summary maps from the respective years (coarse detail), or GIS maps (highly detailed). For example:

   e.g. the apparent 'increase' in total area in more recent assessments compared with 2001, is dominated by habitats located lower on the shore, i.e., towards the MLWS level. Habitats located on the lower shore are more likely to be dominated by muds or sands, and are less likely to contain features such as saltmarshes, rock fields, and artificial structures (with respect to their percentage coverage as a proportion of the total area).

The specific indicator being used is again the extent of soft mud, and the Wriggle report clearly states soft mud did not increase in the lower shore habitats that were more accurately mapped in 2012. As such, the "apparent increase" is real and unrelated to overall changes in the extent of estuary mapped.

10. Specific recommendations from the reviewer:

- *Consider the implications* [of standardisation] *for other broad scale surveys in other Southland estuaries.*

  Response: Agree.

- *Re-evaluate* [broad scale] *data using summary statistics that are less sensitive to total area. Include caveats relating to the implication of variance in total area in the evaluation of change in habitats.*

  Response: Agree, but note this is unlikely to result in any significant change to the primary indicators used in assessing sediment and nutrient impacts on the estuary for the reasons presented above.

- *Re-evaluate changes in habitat coverage using a standardised area. GIS techniques are available for cropping, to ensure a consistent 'frame-size' between years. The downside of this is that it will restrict comparison to the year with the smallest area covered. Another possibility is that each estuary could be separated into two areas (an upper intertidal zone and a lower intertidal zone) that are both standardised and analysed separately.*

  Response: This is readily achievable but has not been done as the most detailed mapping in the Southland Estuaries is that most recently collected. Reducing this information to the year with the smallest area covered (most commonly the first year of mapping undertaken during the development of the NEMP) excludes the best data available. It promotes a lowest common denominator approach which is not supported as it significantly reduces the value of information able to be extracted from the existing data.

- *OR alternatively, if consistent larger areas can be recorded moving forward then establish a new baseline and ignore earlier, smaller area data. The disadvantage of this is that reduces the time series.*

  Response: See previous. The loss of the earliest time series in the estuaries monitored, given the significatant degradation of habitat since then, is not recommended.

- *Sedimentation measurement data from Bushy Point in New River Estuary is unreliable and should be removed from consideration.*

  Response: Disagree, See Comment 5 above. The reviewer has made incorrect assumptions about the assessment techniques used.

- *As multiple sedimentation methods are used and issues of reliability may vary depending on technique, site, and from year to year, it is difficult to discern which historic sedimentation measures are valid and which are flawed. A fuller evaluation of historic data should be undertaken. Reports do not indicate which version of the technique is used at which sites.*

  Response: Disagree See Comment 5 above. Existing data are considered valid and reliable. Only two methods have been used. Historical coring, to retrospectively assess long term changes in the estuary, and sediment plates to enable measurement of sediment rates from an established baseline onwards. The reports clearly state whether sediment plates or historic core rates have been measured, and which are used in assessing sedimentation rates.

- *Greater distances between marker stakes (i.e. 5m), will help to minimise the effects of external disruptions. Using a single reliable method at all sediment sites for comparisons between sites/estuaries is a desired outcome.*

  Response: As per See Comment 5 above, the existing methods are considered valid, reliable, repeatable, and consistent between sites and estuaries. Post spacings were modified to minimise potential surface disturbance above plates prior to the 2013 review and this is one reason for the slightly different plate arrangements noted above. The changed plate arrangement does not alter the reliability of the method.

- *A photo record of each site/plate at the time of sampling would be a useful in the evaluation of reliability with respect to external influences.*

  Response: Photos are routinely undertaken of each site and notes made regarding any factors that may have a influence on results e.g. evidence of recent flood impacts, macroalgal cover, obvious sediment deposition, etc.