Supporting Water Quality Information for the Development of Limits and Targets by the TANK Group: Rivers and Streams

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Environmental Science - Water Quality and Ecology

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Executive summary

Hawke's Bay Regional Council (HBRC) worked with a collaborative stakeholder group in the process of developing proposed Plan Change 9 for the Tūtaekurī, Ngaruroro, Karamū and Ahuriri (TANK) catchments. HBRC scientists were assigned the role to assist a collaborative planning group in its task of making recommendations to HBRC on objectives, policies and methods for freshwater management in these catchments. This report outlines the information provided from water quality and ecology scientists to the TANK Group to support discussion and the setting of objectives and limits for water quality in rivers and streams of the TANK catchments.

The TANK Group began with a 'Structured Decision Making process' by identifying their Values and Objectives in the TANK catchments, and deciding on attributes (or performance measures) and management variables. These were then developed into Policy Options. The decision making approach and terminology were adapted to conform to that of the NPS-FM National Objectives Framework.

This report focusses on the water quality and ecology information for freshwater bodies that was supplied to support the decision making process of the TANK Group. Over a series of meetings scientists presented information with the collaborative group on:

1. Compulsory values and attributes as outlined by the National Policy Statement for Freshwater Management 2014 (NPS-FM 2014)
2. Guidelines that help to understand the state of a freshwater body or a connected value
3. State and trends of water quality and ecology, and specific issues in the TANK catchments
4. Natural characteristics of different waterbodies relevant for evaluating ecological state
5. General in-stream processes and cause-and-effect relationships between land use and water quality
6. Spatial relationships between management options and local and downstream effects

The TANK Group discussed objectives to protect or improve the state of values identified in the TANK catchments in the light of the current state, and set numerical thresholds and identified priority areas to manage. The outcomes were:

The upper Ngaruroro and Tūtaekurī (water quality management area 1), is in a near natural state, and the current state is to be maintained. The water quality in the mainstems of the Tūtaekurī and the Ngaruroro (water quality management area 2) is generally good, but hill country tributaries (water quality management area 3) have issues with high nutrient concentrations and some algal blooms. The receiving environment, the Waitangi estuary is in a declining state and has issues with sediment and macroalgae. The TANK Group decided to reduce sediment and nutrient loads, with the focus on protecting the estuary.

Freshwater quality management areas 4 a–d (macrophyte dominated lowland streams) have issues with ecosystem health as indicated by particularly low MCI, and needs the most improvement. Nuisance macrophyte growth, low dissolved oxygen, high water temperatures and lack of habitat need to be managed. Riparian planting was identified as the main management tool to achieve better ecosystem health. The TANK Group also agreed on reducing nutrients, and sediment in water quality management area 4 to protect the estuary.

The TANK Group agreed on a set of freshwater quality objectives that are compiled in Schedule 1 of TANK Draft Plan Change 9 (Version 8) at the time of compilation of this document. Te Mana o te Wai, kaitiakitanga and the needs for the values set out in Schedule 1, particularly mauri and ecosystem health are achieved through collectively managing all of the specified attributes. For any specific water body where the attribute state is found to be higher than that given in Schedule 1, the higher state is to be maintained and maintenance of a state is at the measured state.

It was a TANK Group desire to include an additional Schedule 2 to satisfy cultural and social needs for a long term and more integrated approach to the way freshwater is managed. It also provides additional direction for the monitoring and research efforts of the Council. This is particularly relevant for the integration of freshwater and estuary ecosystems. Schedule 2 does not have a regulatory function. The quality of the TANK freshwater bodies set out in Schedule 2 will be implemented through future plan changes.

1 Introduction

1.1 The collaborative process to set freshwater quality objectives for rivers

1.1.1 Background

Hawke's Bay Regional Council (HBRC) is in the process of preparing a proposed plan change (Plan Change 9) for the Tūtaekurī, Ngaruroro, Karamū and Ahuriri (TANK) catchments. HBRC worked with a collaborative stakeholder group to determine how these water bodies should be managed. HBRC scientists assisted this collaborative planning group, known as the TANK Group, in its task of making recommendations to HBRC on objectives, policies and methods for freshwater management in these catchments. This report outlines the information provided from water quality and ecology scientists to the TANK Group to support discussion and the setting of objectives and limits for water quality.

Plan Change 9 uses a values based approach to identify objectives for water management in the TANK catchments. This approach, outlined in the National Policy Statement for Freshwater Management 2014 (NPS-FM 2014), requires that the community identify the values for which the water is to be managed, adopt objectives in relation to those values and establish methods, including limits to ensure those objectives will be met.

The TANK Group used a Structured Decision Making process to identify and assess the issues and options for freshwater management in the TANK catchments, and to deliberate alternatives of water body management, costs and benefits. To enable informed decision making, the TANK Group needed sufficient background knowledge. For example, information on water quantity, water quality, land management, and policy options were provided by HBRC scientists and policy advisors. The Group itself made decisions about water body values, and how they were to be provided for.

This report outlines the water quality and ecology information for freshwater bodies that was supplied to support the decision making process of the TANK Group. Over a series of meetings scientists presented information on:

1. Current state and trends of water quality and ecology, and specific issues in the TANK catchments
2. Natural characteristics of different waterbodies relevant to evaluate the ecological state
3. General in-stream processes and cause and effect relationships between land and water
4. Guidelines helping to understand the state of a freshwater body in relation to their identified values

1.1.2 Outline of the decision making process

The TANK Group identified and assessed the issues and options for freshwater management in the TANK catchments. Their analysis contributes to the Section 32 analysis (consideration of alternatives, costs and benefits) required under the Resource Management Act 1991.

To do this, the TANK Group used a Structured Decision Making process. This consists of group members identifying their **Values** and **Objectives**, as well as **Performance Measures**, and **Management Variables**, which are used to identify **Policy Options** and estimate the **Consequences** of these options (some of the terminology was later adjusted to align with the new National Objectives Framework). These terms are defined briefly as:

- **Values**: Activities, uses or sources of value (from freshwater systems), 'things that matter'.
- **Objective**: A desired outcome in a thing that matters (e.g. increase the suitability of water for swimming, generally or in a particular location).
- **Performance Measures (Attributes)**: A specific metric for consistently assessing the consequences of taking an action or set of actions (i.e. criteria for evaluating options). These may later be used to measure and report on the actual outcomes achieved once policies are implemented. The NPS-FM NOF (National Objectives Framework) provides a set of compulsory performance measures referred to as 'attributes'. To simplify and align with the national terminology the term attribute is used in this report.
- **Management Variables:** Aspects of freshwater management that can be directly controlled or indirectly influenced by the HBRC or resource owners/managers (e.g. allocation limits) in order to achieve management objectives.
- **Policy Option**: An action or set of actions, using the Management Variables available, that could be taken to advance the achievement of one or more objectives.
- **Consequence**: An expected result of taking an action or set of actions, i.e. of implementing an option.

Using this framework, the TANK Group first identified and assessed options for the four catchments. Some policy options are generic across the TANK area (e.g. a target for security of supply for water users), whereas others were specific to a catchment or reach (e.g. a flow setting or water quality limit based on a particular use or value). Each option was assessed to estimate its likely consequences in terms of stakeholder values as represented by the performance measures. The Group then tried to refine the policy options to find ways that better met the full set of values, so that everyone had a reason to support it. Details and interim agreements on this first part of the decision making process are outlined in the TANK Group Report1 (HBRC, 2013). Figure 1-7 and Figure 1-8 in Chapter 1.2.5 illustrate the value sets that were identified by the TANK Group.

Key attributes that allow the state of the values to be assessed and monitored needed to be identified and objectives established for them.

Some attributes are compulsory through the NPS-FM (MfE, 2017a): Regional councils are required to

- Safeguard life supporting capacity, ecosystem processes and indigenous species (including their associated ecosystems) of freshwater and the health of people and communities, as affected by contact with freshwater
- Maintain or improve overall water quality within a freshwater management unit
- Set freshwater objectives and limits for all water bodies

The compulsory national values include ecosystem health and human health for recreation. The process for finding the attributes to compulsory values in the NPS-FM is outlined in Figure 1-1. This process was followed with other values the TANK Group identified. Available attributes (guidelines) that relate to the state of the value were presented and discussed, then the most suitable attributes were chosen.

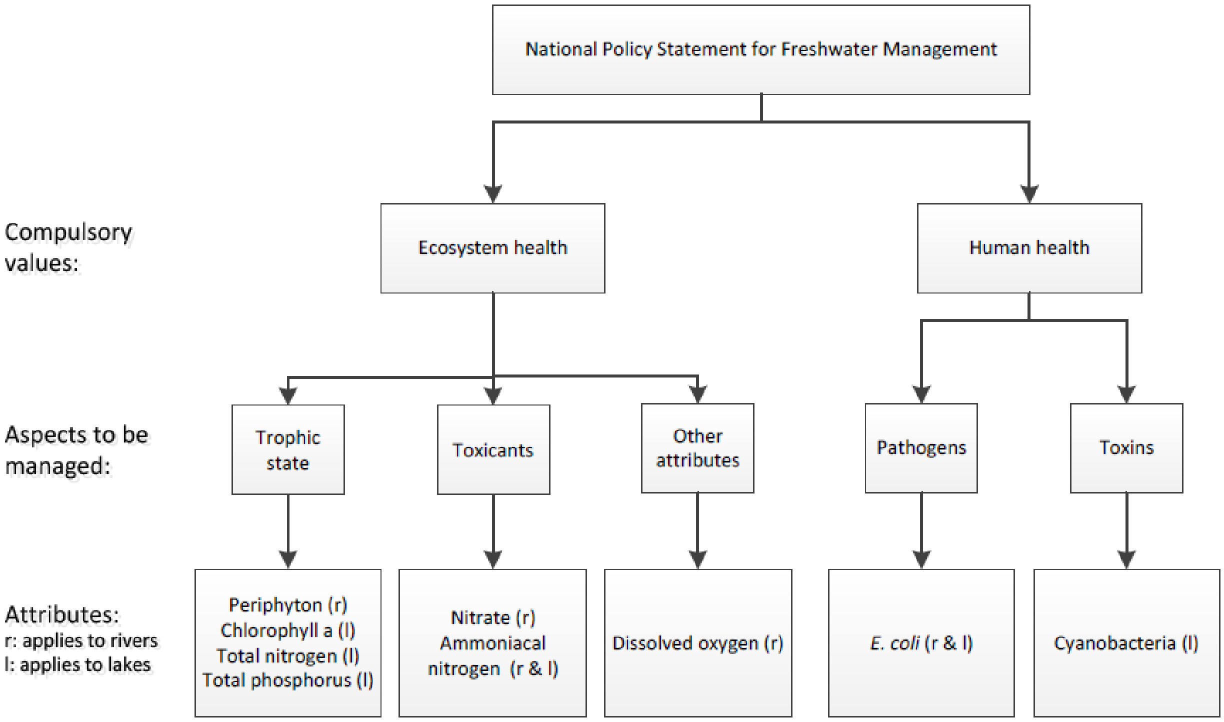


Figure 1-1: Relationship of attributes to the compulsory values of the NPS-FM 2014, Appendix 2.

1.1.3 Outline of the supporting water quality information

The engagement of scientists with the TANK Group stretched over several years in an iterative process as information was needed during the process. Table 1-1 shows a schematic outline on how engagement of water quality scientists and water quality information fitted into the Structured Decision Making process. The table is focussed on water quality and ecology, but also shows interaction with different fields such as hydrology, land science, land management, and policy.

For the structured decision making process the following information and support was provided to the TANK Group in meetings:

1. Attributes suitable to indicate state of values identified by the TANK Group:
    - Attribute – value relationship
    - What does the attribute indicate (threshold levels)
    - Uncertainties, accuracy
    - Monitoring expense / effort
2. Current state of attributes in the TANK catchment
    - Attribute data: how values are currently protected in the TANK catchments (State of the Environment monitoring data)

- Where guidelines are met, or where attributes indicate current state is not meeting the desired state
- Data gaps

3. Supporting information and assistance for the selection of attributes by the TANK Group
4. Supporting information and assistance when setting objectives (level of protection, guidelines thresholds, bands) by the TANK Group
5. Supporting information for setting management priorities
    - Attribute management groups, such as *E. coli*, sediment, phosphorus and DIN (nutrient), nitrate and ammonia (toxicity)
    - Location of problem areas, from SOE data, modelled data

This report focusses on the decision making process for water quality and ecology in streams and rivers of the Tūtaekurī, Ngaruroro and Karamū catchments, and management related to the Waitangi estuary as the receiving environment. Information on values and water quality trigger levels in the Waitangi estuary and the Ahuriri catchment (which is predominantly estuarine), and discussions with the TANK Group were led by marine scientists Anna Madarasz-Smith and Oliver Wade. Wetlands and lakes in the TANK catchments were discussed in a separate working group. Other topics, for example stormwater, drinking water, and channel management, were also discussed in separate groups. Meeting notes and slides on these other topics can be found on the HBRC website under TANK resources:

https://www.hbrc.govt.nz/hawkes-bay/projects/tank/resources/

Table 1-1: **Water quality science involvement in the Structured Decision Making (SDM) process of the TANK Group.**

Step in SDM Process	TANK Group	Water quality scientist	Other experts/analysts
Choosing values	Workshop, identifies values and where they apply		Policy and social science advice
Choosing performance measures (attributes)	Selects performance measures (attributes) using agreed set of principles	Provides information on: • Compulsory attributes (NPS-FM National Objectives Framework - NOF) • Attributes measured for State of the Environment reporting • Attribute-values relationships (what does the attribute indicate?) • Current state of values/ attributes in the TANK catchments • Natural attribute states: River types that have similar ecological functions and characteristics (for appropriate attribute levels)	
Choosing objectives	• Discusses current state of values and attributes • Discusses and agrees on maintain or improve • Agrees on priorities for improvements (low-medium-high priority)	Provides information on: • Land-hydrology-water quality interactions • Current state in relation to objectives set by TANK group ('how far from desired state?')	Provide information on interactions e.g. • Land science: soil/ nutrient losses to water, • Hydrology: water volume/flow - water quality relationships) • Economic, cultural and social impact assessment
Choosing management variables	Discusses and agrees on management variables	Information from Land Management, Land Science, Hydrology, Water Quality, and Policy teams on available management options and their effects, economic, cultural and social impact assessment	

The TANK process stretched over several years (commencing in 2012), and data, information and available guidelines changed during this period:

1. More data became available such as SOE data and data from additional short-term sites to inform the TANK process ('gap-sites'), continuous temperature data. During the decision making process, the 5-year state and trend SOE data (2009-13) were consistently used to avoid confusion with potentially changing values over time. Towards the end of the plan change process a 3-year dataset (2014-16) was introduced to compare the consistency of the data.
2. Overseer and SOURCE nutrient modelling data
3. More guidelines became available, for example on nutrient concentration - algal cover relationships (Matheson et al., 2016), NPS-FM periphyton attribute note (MfE, 2018a), or guidelines changed (NOF *E. coli* attribute (MfE, 2017b)).

Amendments were discussed and incorporated, in line with these changes over time. Towards the end of the process it was becoming more difficult to discuss changes in detail due to the timeframe of the TANK Process.

1.2 Prerequisites to set freshwater quality objectives for rivers

The TANK Plan Change was underpinned by a significant amount of scientific information including that derived from a wide range of new investigations and modelling. To assist in the development of the science programme, a Technical Advisory Group (TAG) was established by HBRC's Group Manager Resource Management. The TAG advised HBRC on science related matters to ensure that science experts were consistent in the approach being taken to fill the science gaps (Sharp, 2015). TAG members were representatives from organisations including Cawthron Institute, NIWA, GNS, Plant and Food, Fish and Game New Zealand, Department of Conservation, Twyford Irrigator Group, Ngāti Kahungunu Iwi Incorporated, Te Taiao Hawke's Bay Environment Forum.

1.2.1 Monitoring sites

HBRC has carried out water quality monitoring across the TANK catchments since 1980 as part of the State of the Environment (SOE) programme. The SOE monitoring programme was undertaken quarterly until June 2012, when monthly sampling began across the whole region.

Over this time a total of 21 sites have been sampled in the Tūtaekurī and Ngaruroro catchments (Figure 1-2). Of these, 14 sites are HBRC's long-term SOE monitoring sites, two sites are monitored long-term by NIWA and 7 sites were sampled additionally since 2012 to fill in knowledge gaps in some of the tributaries without long-term SOE data. These were referred to as 'gap sites'. Eight sites have been sampled in the Karamū catchment, and one in the Ahuriri catchment (Figure 1-3).

Due to the shorter dataset available at gap sites, statistical results on the current state had to be evaluated with caution (e.g. maxima or 95th percentiles for toxicity attributes and *E. coli*), and the limitations comparing long-term SOE site statistics with gap sites were discussed with the TANK Group.

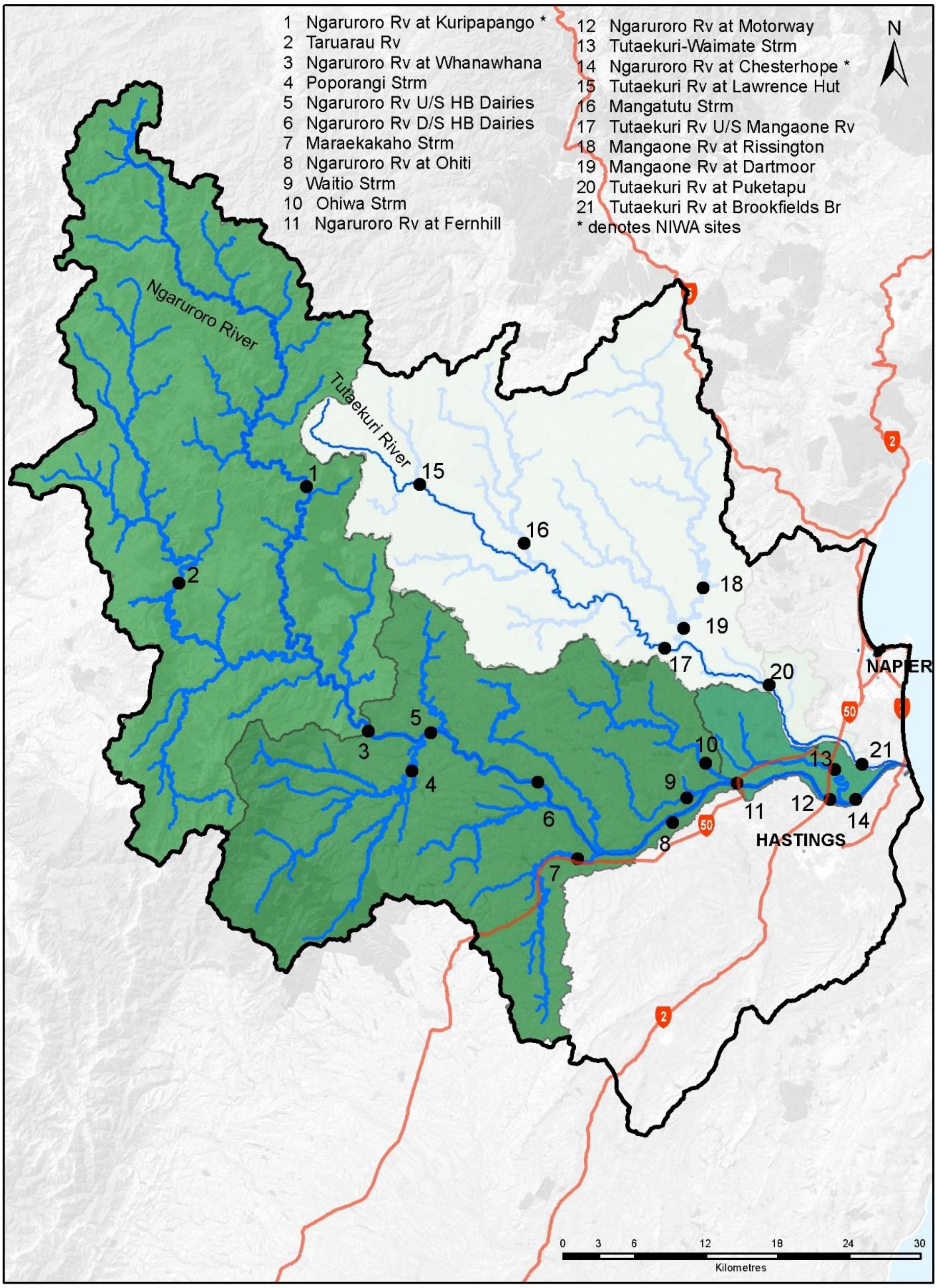


Figure 1-2: **State of the Environment (SOE) monitoring sites for water quality and ecology in the Ngaruroro River and Tūtaekurī River catchments.**

Figure 1-3: State of the Environment (SOE) monitoring sites for water quality and ecology in the Karamū and Ahuriri catchments.

1.2.2 Water quality and ecology data for the TANK process

Information on state and trends of water quality and ecological indicators in the TANK catchments was provided in several presentations over the first part of the collaborative process. The information was based on the 2013 5-year State of the Environment (SOE) report (Haidekker et al., 2016) throughout the plan change process to avoid confusion. Only gap sites were updated to increase confidence in the comparatively short dataset, and results of targeted studies were included when they became available. Towards the end of the TANK process the dataset was updated with the 2014-16.

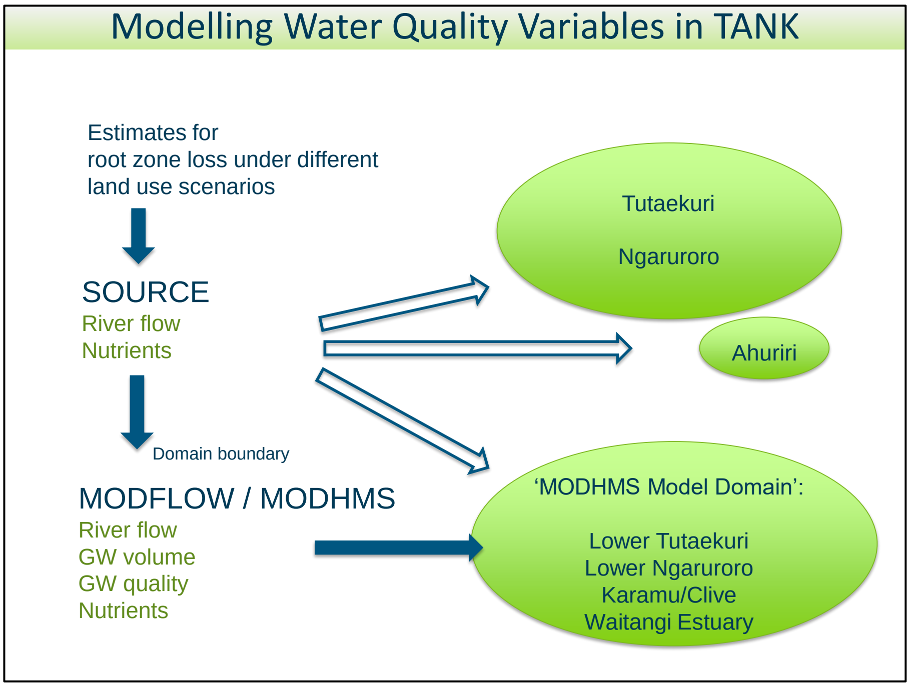
Discussions held on the TANK catchments were structured in a way to reflect the natural differences in ecological systems between catchments, and their effect on values. There was a special focus on the difference between macrophyte dominated lowland areas and algae dominated hill country areas, as well as smaller tributaries and the wide, often braided channels of the mid to lower main-stem of the Tūtaekurī and Ngaruroro. The grouping to ecological surface water quality areas is based on the Freshwater Ecosystems of New Zealand (FENZ) model (Leathwick et al., 2010b). The TANK ecological surface water management areas are outlined in more detail in Chapter 1.2.4.

In addition to managing freshwater quality for in-stream values in the TANK catchments, these areas also have to be managed regarding their downstream effect, the receiving estuaries. The values and state of the TANK estuaries (Ahuriri and Waitangi estuaries) were discussed separately with the TANK Group, by HBRC marine scientists Anna Madarasz-Smith and Oliver Wade. Madarasz-Smith (2018) summarises guideline levels for the estuarine/marine environment.

Not included in this report are wetlands, lakes, stormwater and drinking water. These topics were dealt with in separate working groups.

1.2.3 Modelled data to support setting management priorities

SOE and 'Gap' sites, which were monitored from the start of the TANK process to increase the number of monitored sites in the TANK catchments, provide 'real' data, but only monthly values and with a limited spatial cover of the TANK catchments. A model (SOURCE) was used in conjunction with the surface water – groundwater model MODFLOW to predict Total Nitrogen (TN) and Total Phosphorus (TP) loads and concentrations for streams and rivers in the TANK catchments (Figure 1-4). Technical details on the model are reported in Williamson and Diack (2018).



Modelling Water Quality Variables in TANK

Estimates for
root zone loss under different
land use scenarios

SOURCE
River flow
Nutrients

Domain boundary

MODFLOW / MODHMS
River flow
GW volume
GW quality
Nutrients

Tutaekuri
Ngaruroro

Ahuriri

'MODHMS Model Domain':
Lower Tutaekuri
Lower Ngaruroro
Karamu/Clive
Waitangi Estuary

Figure 1-4: Conceptual overview on TN and TP modelling in the TANK catchments. This was a slide presented at a TANK Group meeting on 15 July 2015, showing the integration of SOURCE and the surface water-groundwater model MODFLOW.

For sediment the SedNet model was used to predict sediment loss and transport in the TANK catchments. As with the SOURCE model, the results were used to facilitate setting priorities and identifying priority catchments for erosion management. Palmer et al (2016) provide details on the SedNet model.

The TANK Group discussed the uncertainty of model results compared to monthly spot samples. It was agreed it was helpful to use the SOURCE and SedNet models to identify 'hot spot' sub-catchments and set priorities in nutrient and sediment management.

1.2.4 FMUs and ecological surface water management areas

The term freshwater management unit (FMU) was introduced to the National Policy Statement for Freshwater Management (NPS-FM) in the 2014 amendments. An FMU is defined in the NPS-FM 2014 as:

A water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management.

The Guide to Identifying Freshwater Management Units (MfE, 2016) states: The definition of FMUs is intentionally flexible so councils can determine the spatial scale best suited to managing fresh water in the specific circumstances of their region. Management includes setting values, objectives, limits, and undertaking freshwater accounting and monitoring.

In the TANK process, freshwater management areas of similar ecological characteristics were defined in the first step of considering water quality and ecosystems. These were set to reflect similar problems in relation to freshwater ecosystem health, ecological characteristics and values, and are therefore areas requiring similar management in this particular aspect. For example, hard-bottomed, algae dominated hill country streams tend to have different issues and therefore need different management responses, compared to lowland streams that are dominated by soft sediment, and macrophytes. For the TANK Plan Change, four major ecological areas were defined using the predominant FENZ class as a high-level classification system. Freshwater Ecosystems of New Zealand (FENZ) is a classification system that groups surface water bodies based on similar ecological character (Leathwick et al., 2010a) (Leathwick et al., 2008). The classes were developed including biological data. The FENZ classes in the TANK catchments are summarised in Table 1-2, and the classes are shown in the map for the TANK catchments (Figure 1-5).

The ecological freshwater management areas had to be scaled up in order to contribute to a common objective being set for an FMU, and meeting the needs of the NPS-FM. The four catchments of the TANK area were identified as FMUs reflecting the hydrological, physical and community/cultural boundaries to set common freshwater objectives and limits, and to protect the values of the receiving estuaries. Monitoring sites in each of the catchments are: Tūtaekurī at Puketapu, and Ngaruroro at Fernhill (already monitored) and sites in the Karamū and Ahuriri were added to the monitoring network as a result of the plan change process.

A further consideration to establishing four catchment FMUs was the resources needed to apply the monitoring requirements of the NPS-FM: For example monthly periphyton biomass (for Chlorophyll *a*) monitoring is required for each FMU. The faster and more economical visual assessment of periphyton cover is more informative in relation to values, as it covers guidelines for recreation, fishery, and ecosystem health, whilst also having nutrient concentrations recommended to achieve periphyton cover objectives (Matheson et al., 2016) . This is more informative and more applicable to community values than algal biomass. Algal biomass assessment is labour intensive and has additional lab costs, whilst being only linked to ecosystem health, and the assessment is limited in its applicability as scrapes for algal biomass are dependent on gravel size suitable for this protocol. Periphyton cover can be monitored at more sites without compromising the limit setting process.

An FMU requires water volume, as well as nutrient and sediment loads to be calculated, which does not align well with the cross-catchment water quality areas. There would need to be a prohibitive amount of monitoring of catchment units within water quality areas to be able to manage these in an FMU framework. FMUs were therefore delineated based on catchments, whereas water quality areas were delineated based on the physiographic drivers (which were common among the lower parts of different catchments, for example).

As such, we proposed aligning FMUs with water catchments, rather than water quality areas, to achieve a pragmatic balance between detail and the costs of comprehensive monitoring required to collect data to inform management and accounting in an FMU framework.

Table 1-2: FENZ classes in the TANK catchments. (Leathwick et al., 2010a) amended for the Hawke's Bay Region (Clapcott and Goodwin, 2018).

TANK area description	**TANK area**	**FENZ Class**	**FENZ classification amended for HB region**
upper Ngaruroro and Tutaekuri catchments	1	C7C10	Small streams with unstable flows, in moderately inland, mid-elevation locations with cool to mild climates and low frequency of days with significant rainfall. Stream gradients are generally steep to very steep, and with predominantly coarse gravel.
upper Ngaruroro and Tutaekuri catchments	1	G	Small, coarse gravel streams in inland locations in cool climates and very low frequency of days with significant rainfall. Generally moderate gradients and unstable flows.
upper Ngaruroro and Tutaekuri catchments	1	H	Small, cobbly streams in inland locations in cool climates and low frequency of days with significant rainfall. Steep gradients and moderately stable flows.
Ngaruroro and Tutaekuri Mid-low main stems	2	C4	Rivers with unstable flows, in moderately coastal locations, maritime climates and low frequency of days with significant rainfall and moderate flows.
Hill country tributaries	2 / 3	C6	Larger streams with unstable flows, moderately inland locations with warm climates, low frequency of days with significant rainfall and a predominance of coarse gravelly substrates. Gentle slopes.
Hill country tributaries	3	C1C5	Very small to small streams with unstable flows in mild, maritime climates and low frequency of days with significant rainfall. Stream gradients generally moderate to steep, and predominantly coarse gravels.
Hill country tributaries	3	C8C9	Small inland streams with mild climates and a low frequency of days with significant rainfall, moderate gradients and generally gravel substrate.
Lowland tributaries	4	A	Mostly small streams in coastal or inland locations with gentle gradients and generally silty or sandy substrates, although hard substrates are present in some reaches of this class.
Other streams mainly upper Ngaruroro and Tutaekuri		C*(other) *(other)	Other FENZ classes that together represent less than 1% of the stream network in Hawke's Bay

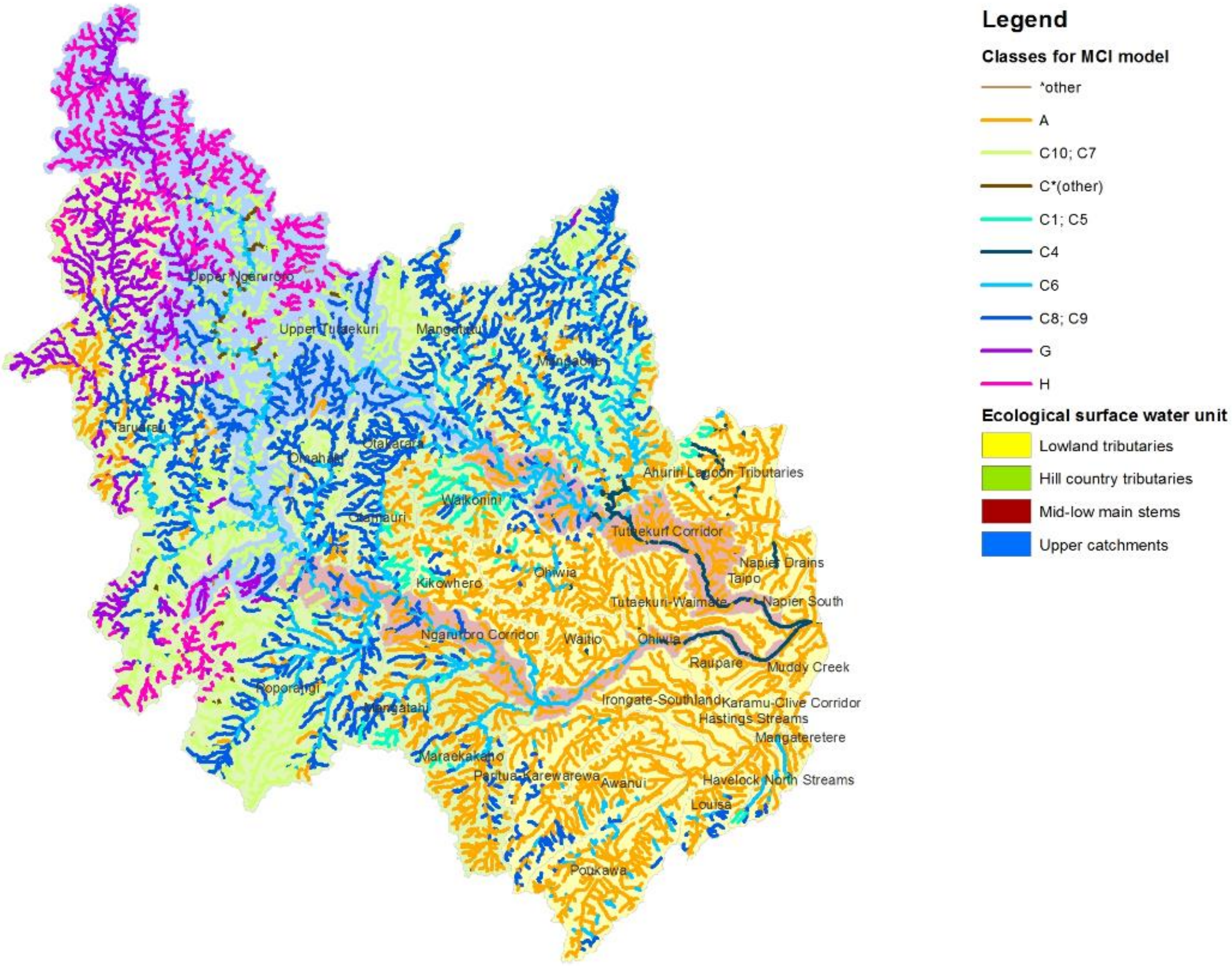


Figure 1-5: Map of FENZ stream and river classes in the TANK catchments. Background colours TANK surface water quality areas, which are ecological areas based on predominant FENZ classes.

The map in Figure 1-6 shows the TANK surface water quality areas to be managed with points indicating the SOE sites.

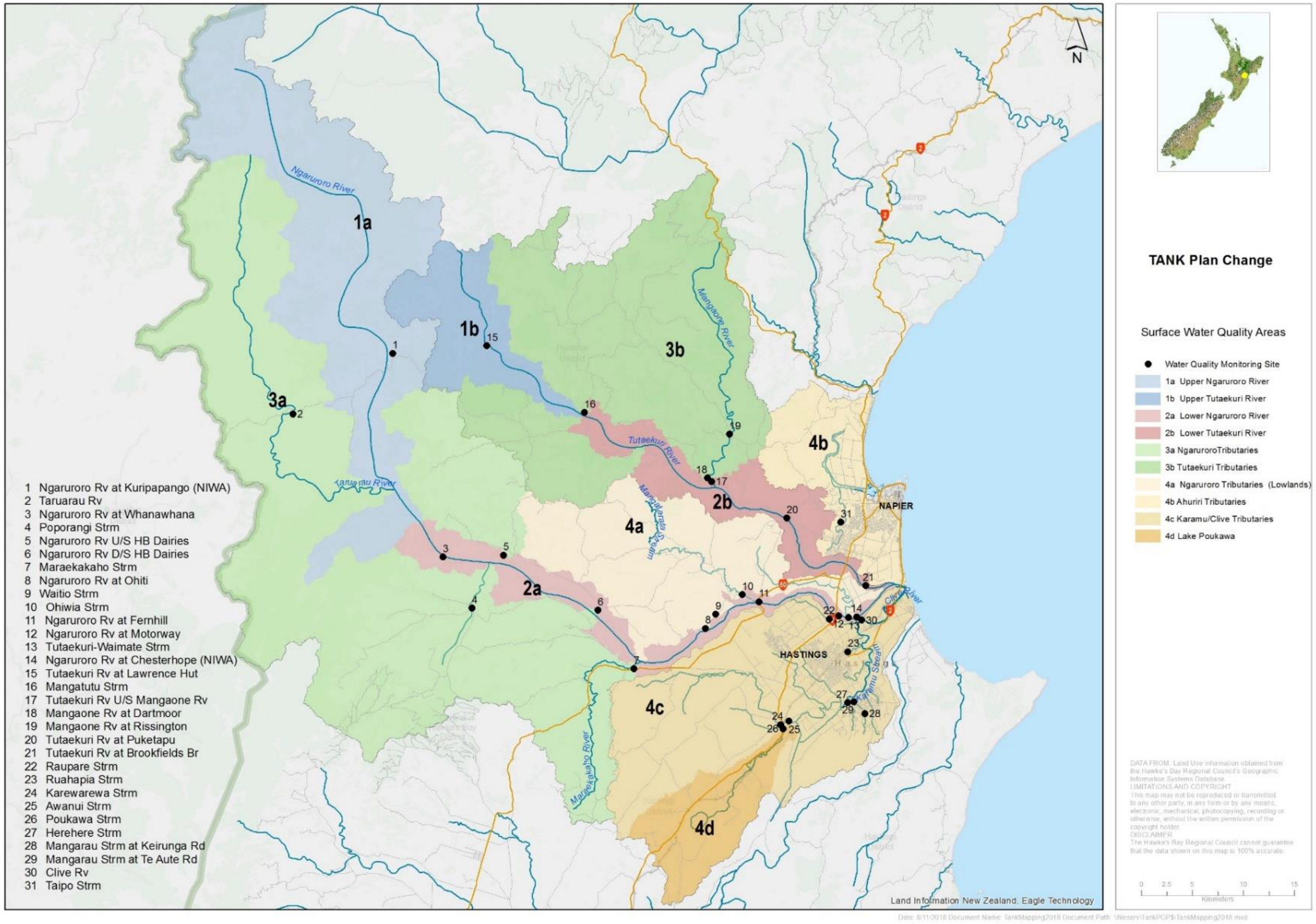


Figure 1-6: TANK surface water quality areas for management in Plan Change 9 with SOE monitoring sites.

1.2.5 Values in the TANK catchment

National Policy Statement for Freshwater Management

The NPS-FM (MfE, 2017a) requires regional councils to set freshwater management objectives based on both national and local values as stated in the preamble of the NPS-FM. Appendix 1 in the NPS-FM lists compulsory and other national values.

Compulsory values in National Policy Statement for Freshwater Management 2014 (MfE, 2017a)

Appendix 2 of the NPS-FM (MfE, 2018b) contains two compulsory national values: ecosystem health and human health for recreation, for which councils must set freshwater objectives in each Freshwater Management Unit (FMU) in the regional plan. The freshwater objectives for the compulsory values must employ the attributes provided in Appendix 2 plus any other attributes the council considers appropriate. Other national values in the NPS-FM Appendix 1 were included in the TANK Group's discussions to identify values as outlined below.

Values identified by the TANK Group

The TANK Group started with an introduction to values in October 2012 at the beginning of the TANK process. The identification and discussion on values was an iterative process, with key meetings and outputs being the TANK Group report 1 interim agreements (HBRC, 2013), values mapping (Meeting 13; July 2014), a second workshop on additional sites for values mapping (Workshop May 2015), and the report 'Ngaruroro values and attributes' (McArthur et al., 2016).

During this process, critical 'key' values were identified.These would protect other values and were seen as being the most sensitive and needing highest protection out of a values set (e.g. management for trout fishery would also protect eel fishery and native fish in general). This process helped to keep the amount of values and attributes at a manageable number.

Additionally, gaps were identified where the state of a value was not known due to a lack of data on relevant attributes. Potential relevant changes and additions to monitoring programmes were identified to accommodate these gaps (e.g. attributes for values in lakes and wetlands, fish surveys, bird counts).

The TANK Group identified values in the four catchments as the first step in the Structured Decision Making process. The report 'Inventory of Values in the TANK Catchments' (Sinner and Newton, 2016) compiles available spatially-referenced information on the uses and values of freshwater in the TANK catchments.

The report summarises values in the following broad categories:

- Ecological and intrinsic values
- Cultural values
- Social and recreational values
- Commercial and other 'out of stream' values
- Property protection values.

Identification of a value by its inclusion in the values report did not represent any particular level of protection for that value. The report gives no assessment of the significance of any values (except where reporting assessments have been done by others, see below), nor is there any attempt to compare the significance of one type of value with any other.

The River Values Assessment System, or RiVAS, is a multi-criteria method for assessing the relative significance (i.e. contribution) of rivers within a region for a particular use or value (Hughey and Baker, 2010, Hughey and Booth, 2012). Using RiVAS, an expert group assessed rivers within the region for their significance for a particular value, which requires weighting the importance of the various attributes of that value as identified by the expert group (Sinner and Newton, 2016).

In Hawke's Bay, the RiVAS methodology has been applied to the following values:

- Salmonid angling
- Native fish
- Native birds
- Natural character
- Kayaking
- Irrigation
- Swimming.

The RiVAS assessments provided depth, including spatial detail to the overall understanding of these value in relation to Hawkes Bay Rivers. They provided information about the relative importance or significance of rivers for each of the values, but not comparatively with other values. The decision making by the TANK group did not assign significance to values, but used this information to understand where the values were important.

For the in-stream freshwater quality and ecology values (relevant to this report), existing attributes - were identified that (1) were of direct relevance to the values (2) related to the state of the value and (3) where current state data was available. Some values did not have data available related to the current state. The lack of information meant discussion on state and objectives could not be held, and future work would need to be done on defining attributes and acquiring data for these values, before objectives or limits could be set.

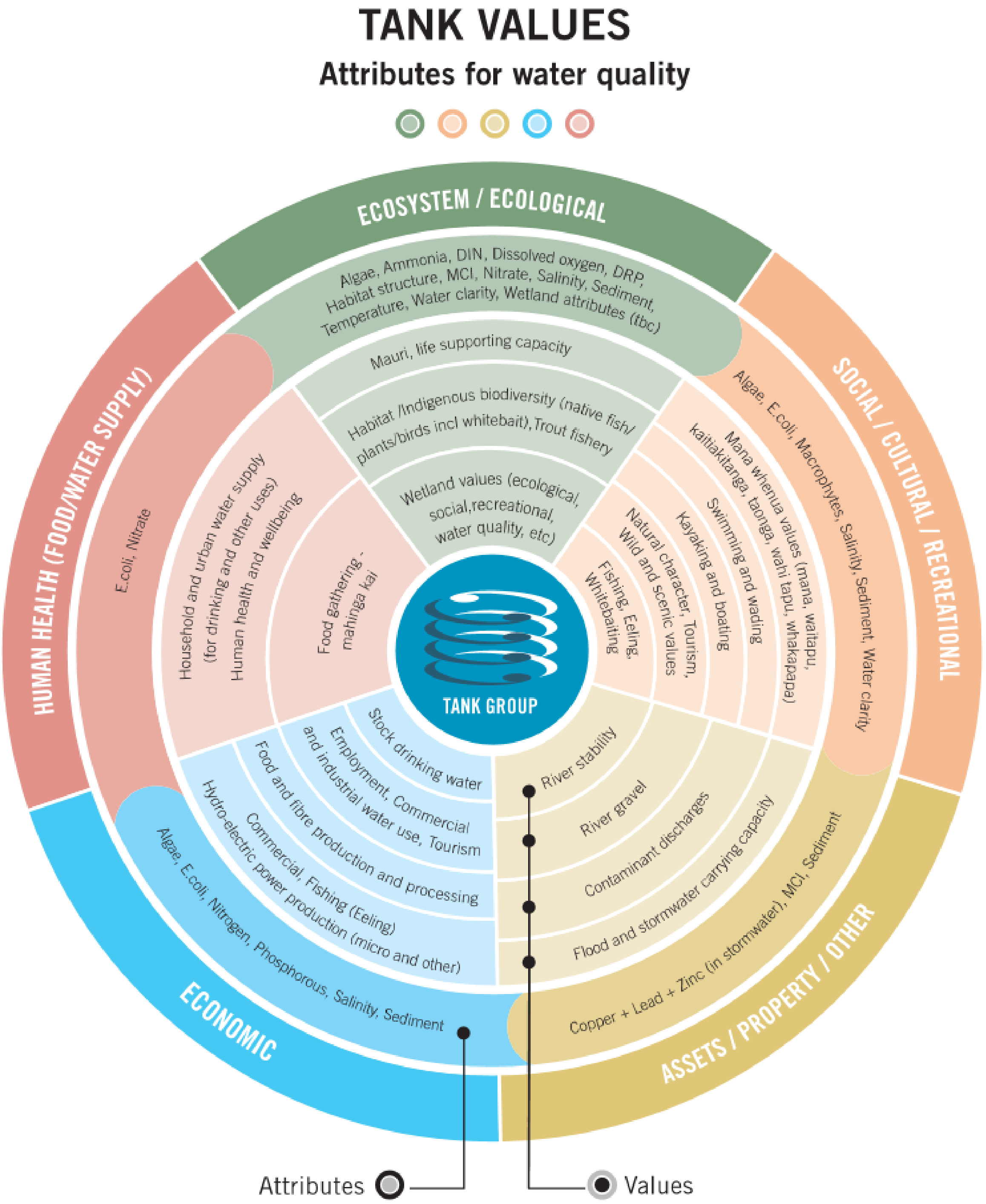
Tangata whenua values

Many tangata whenua values relate to all waters in a catchment, both surface and groundwater, and only some have been mapped. Further, where values are specific to a site, this information is often culturally sensitive and confidential. Information about tangata whenua values was collated and reported (Ngaruroro and Tūtaekurī rivers) and this as well as reference to Iwi Management Plans helped the TANK Group better understand Māori values and how they need to be provided for. Assessment as to how these values are provided for was in part done by considering the state of the common attributes identified by the wider TANK Group and mana whenua, as provided for in the Ngaruroro Values and Attributes report (McArthur et al., 2016). Further analysis on how Māori Values have been accounted for was provided by a Cultural Values Alignment analysis and is reported on separately and is contained within the section 32 report.

Attributes related to the identified values are listed in Table 8 and 9 (p 53 ff.) in the Ngaruroro Values and Attributes Report (McArthur et al., 2016). The attributes listed for water quality (Table 8) were discussed by the TANK Group for objectives and limit setting. Only three attributes could not be discussed due to lack of data: Lake nutrients and phytoplankton, and BOD (Biochemical Oxygen Demand). The TANK Group also discussed the following attributes of Table 9 (physical and flow attributes) in the Ngaruroro Values and Attributes report: Stock access, shade, riparian condition, habitat heterogeneity and nuisance weed % cover (periphyton and macrophyte abundance in this report). Flow attributes and discharges, stormwater, flood control work and gravel management were dealt with by other sections or working groups and these are not covered in this report.

Data gaps were recorded, for example deposited sediment, continuous monitoring, fishery surveys. The monitoring programme was changed or will in future change to accommodate these gaps.

In July 2018 a document ‘Freshwater values and attributes – water quality recommendations to support mana whenua values for the TANK catchments’ became available, that recommended hapu management zones and recommended numeric objectives for water quality variables. It was not possible to process and discuss these values with the TANK Group as the collaborative process was coming to an end at that stage, but this information in consultation with the Mana Whenua Working Group led to the refinement of the Freshwater Management Units and the subsequent preparation of the planning maps. TANK values and attributes are summarised in Figure 1-7 and Figure 1-8.



- **Algae** - Includes periphyton, the algae found naturally on river beds, and phormidium, the cyanobacteria that can cause dog deaths
- **DIN** - Dissolved Inorganic Nitrogen, **DRP** - Dissolved Reactive Phosphorus
- **Economic** - Recreational and water supply attributes are also relevant
- **Māori** - Values and attributes are being further developed with tāngata whenua
- **MCI** - Macroinvertebrate index

Figure 1-7: Community values and attributes for water management.

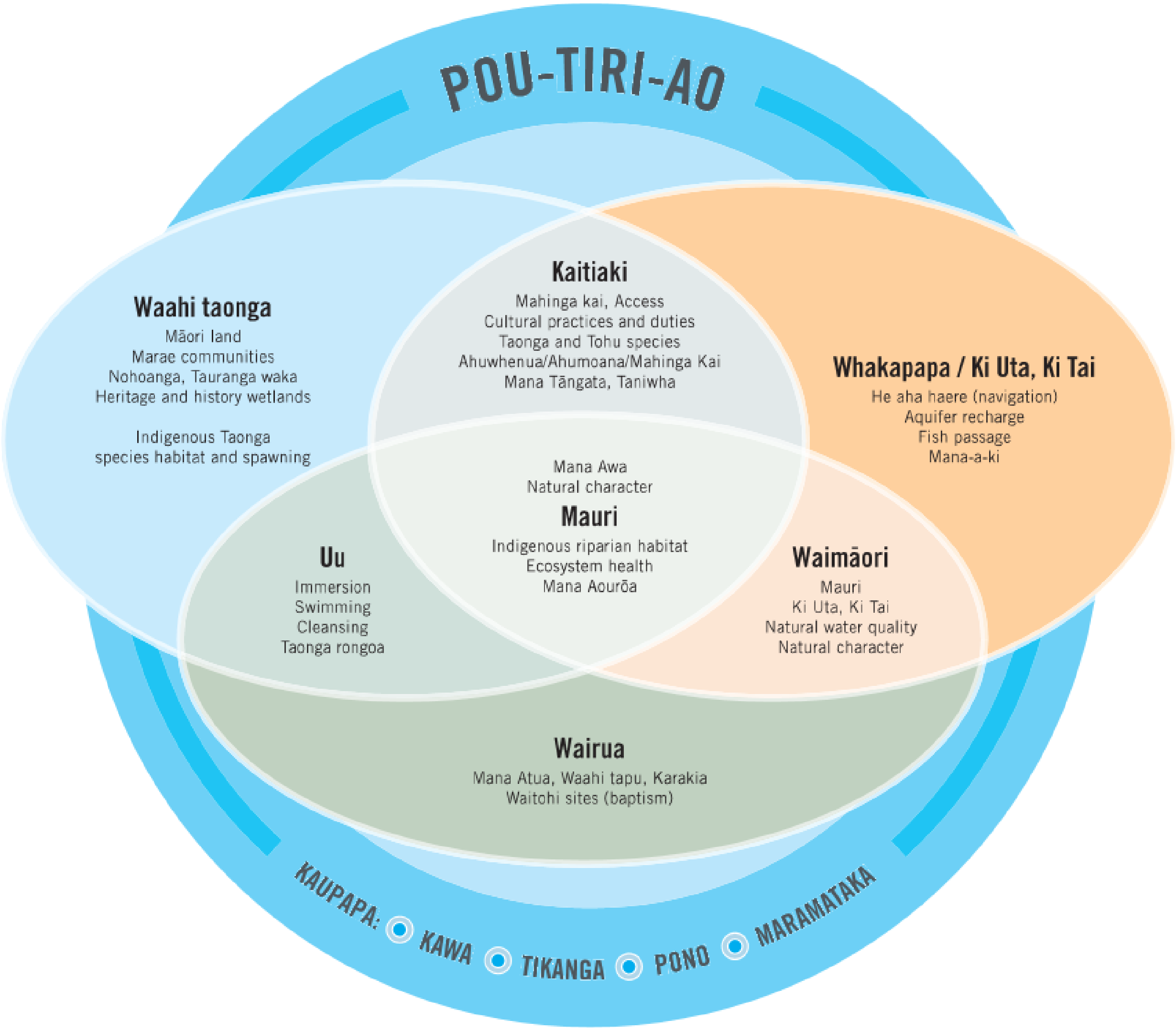


Figure 1-8: **TANK values Te Ao Maori 2017.**

1.2.6 Criteria for selecting guidelines / attributes for water quality objectives

Attributes are performance measures or indicators that are related to values and indicate a quality state. It is a metric that can measure changes over time in response to implemented policies and other changes in the catchment. The NPS-FM outlines ecosystem health and human health as national compulsory values with attributes for rivers and lakes. The attributes which include periphyton, nitrate toxicity, ammonia toxicity, and dissolved oxygen (below point source discharges) are compulsory attributes for ecosystem health while *E. coli* and cyanobacteria are compulsory attributes for human health (i.e. suitability for recreation). There are several other options for attributes that could be used to manage water at a regional scale, including reference to scientific publications that link indicators (attributes) to a value state, or national or international guidelines (e.g. ANZECC, RMA, RRMP). Attributes and related values identified by the TANK Group are listed in Table 1-3.

To choose attributes for freshwater quality objectives in the TANK plan, guidelines or indicators were considered in the following order:

- NPS-FM Attribute (compulsory values ecosystem health and human health for recreation)
- NOF attribute discussion papers
- Published thresholds that relate to state of identified values (e.g. water clarity – trout)
- Statistical trigger values (e.g. ANZECC)
- HBRC Regional Resource Management Plan (RRMP)

If the first is not available for a specific value, then the second is chosen. In the case of several values with different thresholds the most stringent value is selected that supports all values. Less stringent guidelines may not always be separately mentioned in the tables or text.

Attributes to be managed were grouped into functional groups, e.g. phosphorus, sediment and *E. coli* are in a management group, because they enter the streams through surface runoff and erosion.

Not every existing water quality or ecology indicator will be used as a limit or threshold, only the critical attributes related to identified values, and attributes with a statistically viable dataset to support information on the current state. Thresholds for attributes that are not currently measured (e.g. continuous pH) guidelines are provided from literature for future reference. These were not discussed in detail with the TANK Group.

During the TANK stakeholder group process more guidelines became available and amendments to the NPS-FM were made, some after the Group discussed the respective attribute. This is the case particularly for NOF *E. coli* and the periphyton attribute note.

Table 1-3: Summary of attributes and related values as identified by the TANK Group. Shaded in grey: No SOE data available, default values used. [1]From Ngaruroro Values and Attributes Report (McArthur et al., 2016)

	Ecosystem Health	Recreation / aesthetics	Fishery	Estuary ecosystem health	Tangata Whenua Values[1]
Water clarity	X	X	X	X	X
Turbidity	X	X	X	X	X
Deposited sediment	X	X	X	X	X
Periphyton - biomass (NOF)	X				X
Periphyton and cyanobacteria - cover	X	X			X
Macrophytes	X	X	X		X
Nutrients (TN, TP, DIN, DRP)	X			X	X
Toxicants (nitrate, ammonia)	X		X	X	X
Dissolved oxygen	X		X		X
Temperature	X		X	X	X
Macroinvertebrate indices	X		X		X
pH	X		X		X
other toxicants, metals, metalloids	X		X	X	X
POM (Particulate Organic Matter), BOD etc.	X		X	X	X

2 Supporting water quality information to set freshwater quality objectives

2.1 Information on current water quality guidelines suitable as attributes

2.1.1 Water clarity, turbidity, deposited sediment

Fine sediment is defined as particles < 2 mm and consists of sediment commonly called sand, silt and mud. It originates naturally from weathered rock (by wind, water, ice), gets into waterways and is transported until it is eventually deposited. Human activities accelerate the delivery of sediment to streams and increase the quantity of fine particles in the water. This leads to decreased water clarity and increased turbidity, and the sediment is deposited on the stream bed and the estuary.

Water clarity is important for the protection of contact recreation values, because it directly affects the water's aesthetic quality for recreational users. In addition, adequate visual clarity allows swimmers to estimate depth and identify subsurface hazards (ANZECC, 2000).

A reduction in water clarity can also affect the foraging ability of fish, such as trout, by reducing their ability to see food drifting in the water column (Shearer and Hayes, 2010). Trout hunt visually and drift feeding is their main foraging behaviour in most rivers (Hay et al., 2006). Reduced visual clarity (or equivalent increases in water turbidity), reduces foraging efficiency (i.e. more energy is spent consuming the same amount of prey, or fewer prey are consumed).

Deposited sediment on the stream bed and the estuary affects aquatic communities by reducing refugia of aquatic organisms such as macroinvertebrates and fish by clogging spaces between river gravel, and altering the availability of food sources (Clapcott et al., 2011).

There is a direct relationship between water clarity as measured using a black disc, and turbidity. The higher the turbidity the lower the water clarity. At very low turbidity levels a small increase in turbidity results in a large decrease in black disc distance. Turbidity readings less than 1 Nephelometric Turbidity Unit (NTU) typically produce black disc distances greater than 3.5 m, which are distances optimal for drift feeding trout (Hay et al., 2006). Such turbidity readings reflect very low numbers of suspended particles in the water column. Very minor increases - whether caused by the presence of soft-sedimentary geology like mudstone or papa rock, or by minor catchment disturbance causing increased sediment transport - will cause minor increases in turbidity and rapid reductions in water clarity. Heavy rain and associated floods mobilise catchment sediment and cause substantial turbidity increases, of 500 NTU or more. Davies-Colley (2009) recommends against the use of turbidity for guidelines because this measure doesn't have an absolute physical calibration, but turbidity could be used locally when used in conjunction with visual clarity or suspended solid concentration. In a study on suspended sediment attributes Depree (2017) recommends using turbidity for comparability (all New Zealand councils measure turbidity, but not all measure clarity), and because turbidity is more suited than clarity for managing at the impacted, more turbid spectrum of water quality.

ANZECC (2000) and the HBRC RRMP (HBRC, 2006a) define a minimum water clarity of 1.6 m for contact recreation waters. However, to maintain the foraging efficiency of drift feeding trout Hay et al. (2006) recommend a minimum water clarity of 5 m for outstanding or regionally significant trout fisheries and 3.75 m for trout fisheries of lesser importance at baseflow conditions (river flows < median).

Hay et al. (2006) recommend a median turbidity of ≤0.5 NTU for outstanding trout fishery, and ≤0.7 NTU for significant trout fishery at less than median flows. ANZECC (ANZECC, 2000) defines an upland trigger value of ≤4.1 NTU and a lowland trigger value of ≤5.6 NTU (Table 2-1).

Water clarity is determined by measuring the horizontal distance that a black disc of standard size can be viewed under water. Where streams are big enough, black disc measurements are carried out monthly at all HBRC SOE monitoring sites. Also turbidity is measured monthly at all sites.

Table 2-1: Discussed water quality values for clarity and turbidity.

attribute	value	source	guideline context / band / level of protection	numeric value	application
Clarity	Trout fishery	Hay *et al.* (2006)	outstanding trout fishery	> 5 m	median, <median flows
			other significant trout fishery	>3.75 m	median, <median flows
	Recreation	ANZECC (2000)		> 1.6 m	not specified
Turbidity	Trout fishery	Hay *et al.* (2006)	outstanding trout fishery	0.5 NTU	median, <median flows
			other significant trout fishery	0.7 NTU	median, <median flows
	Ecosystem health	ANZECC (2000)	statistical default guideline for upland rivers	≤ 4.1 NTU	not specified
			statistical default guideline for lowland rivers	≤ 5.6 NTU	not specified

There was a specific request by stakeholders in TANK meeting 39 to also include turbidity as an additional attribute to clarity. The TANK Group identified trout fishery as a value for the upper catchments of the Tūtaekurī and Ngaruroro, whereas the tributaries and the lowland areas were to be managed for recreation and ecosystem health. In meeting 39 the TANK Group discussed the ANZECC guideline of >1.6m clarity for recreation: this was not seen as sufficient to also protect Kaitiakitanga in water management areas 2 and 3. The TANK Group suggested taking the threshold of ≥3.75m clarity for significant trout fishery as a higher protection level instead of the ANZECC guideline ≥1.6m.

Deposited sediment has not been used widely due to lack of standardised protocols until 2011, and inter-user variability and noise in the data make it currently difficult to apply this measure as a limit. Recommended guidelines for deposited sediment are: less than 15% fine sediment cover to protect salmonid spawning habitat, less than 20% cover for ecosystem health, and less than 25% cover to protect amenity values (Table 2-2). Clapcott & Hay (2014) recommend adopting a guideline of 20% fine sediment cover, or less than 10% increase in fine sediment cover in comparison to a reference condition. These guidelines were derived from correlation of sediment cover with instream health indices and catchment land-use. However Clapcott et al. (2011) note, that there are likely to be lower limits at which instream values will be negatively affected, but it is difficult to determine lower limits because of the above mentioned noise in the data. Some regions have applied a lower threshold (e.g. Canterbury Natural Resources Regional Plan 2010: between < 10% and < 40%, depending on management class, Hawke's Bay Regional Council PC 6 < 15%, Horizons Regional Council 15–25% depending on water management subzone).

Table 2-2: Discussed water quality values for deposited sediment.

Attribute	**Value**	**Source**	**Guideline context / band / level of protection**	**Numeric value**	**Application**
Deposited sediment	Ecosystem health	Clapcott *et al*. (2011)	Biodiversity (MCI)	< 20%	Maximum, run habitats, at all times
	Trout fishery		Salmonid spawning habitat	< 15%	Maximum, May - Oct
	Recreation		Amenity	< 25%	Maximum, run habitats, at all times

2.1.2 Periphyton and cyanobacteria – biomass and cover

Algae are found in many locations in rivers. They may drift in the water column in both rivers and lakes, but they are called periphyton when they are attached to objects underwater such as the streambed gravel, rocks, logs, branches or any other stable material.

Low levels of algal growth occur naturally in healthy riverine ecosystems. Algae are the main primary producers in hard bottomed streams and rivers, and are fundamental to the functioning of aquatic ecosystems (Biggs, 2000). They support invertebrate and, in turn, fish productivity and diversity. But when periphyton cover grows too thickly, it can detrimentally affect ecosystem health and recreational values. Algal growth is controlled by several biotic and abiotic factors. Biotic factors include grazing by invertebrates and abiotic factors are nutrient availability, available light, and the time available for algae to grow between flood flows that scour algae off the river bed (known as the 'accrual' period).

Regional climate determines the frequency of floods capable of resetting algae to low levels, thereby starting a new accrual period. Catchments in dryer climates generally accumulate more algae between infrequent floods than those in regions with wetter climate and higher flood frequencies (Snelder et al., 2014).

Excessive periphyton growth can have detrimental effects on benthic habitat quality and macroinvertebrates, which can in turn affect native fish and trout growth, since macroinvertebrates are a food source for native fish and trout. Excessive growth can also cause wide daily variation in pH and dissolved oxygen concentrations, which can also detrimentally affect aquatic life (Biggs, 2000). In addition, the benthic cyanobacteria *Phormidium* can be hazardous because it produces toxins.

Excessively long filamentous algae and thick mats are unsightly and can directly affect amenity/aesthetic values of a river, and the quality of fishing for anglers by fouling fishing lures and lines (Biggs, 2000), (Wilcock et al., 2007).

The amount of algae present in a river can be assessed in terms of biomass, measured as the amount of Chlorophyll *a* per area (mg Chl*a*/m^2), or visually as proportional cover on the stream bed (% cover) in a defined reach. Algal biomass is an indicator related to the trophic state aspect of the ecosystem health value in rivers in the NPS-FM, and is used to assess the effects of in-stream nutrient concentrations. The frequency and intensity of algal blooms reflect respective nutrient enrichment (Table 2-3).

The visual assessment of periphyton cover records mats and filamentous algae that have different thresholds in the New Zealand Periphyton Guideline (Biggs, 2000). Matheson et al. (2016) provide guidelines for a composite cover index integrating the different guidelines for mats and filamentous algae, the Periphyton Weighted Composite Cover (PeriWCC). PeriWCC guidelines relate to aesthetic, recreational, angling and ecological condition values (Table 2-3).

Benthic cyanobacteria are a specific type of periphyton that are widespread through New Zealand rivers in varied water quality conditions, including very low nutrient environments. The most common genus is *Phormidium*, which can potentially form toxic blooms. The risk of a cyanobacterial bloom is greatest where water temperature is higher than 15°C, no flushing flows have occurred for at least 14 days, stream bed substrate is hard-bottom, and in unshaded conditions (MfE and MoH, 2009). Cyanobacteria respond differently to nutrients than other algae. Evidence collated in reviews on *Phormidium* (Wood et al., 2017 and McAllister et al., 2016), suggest blooms occur under nitrogen enriched conditions, when DRP concentrations are less than 0.01 mg/L. NZ interim guidelines (MfE and MoH, 2009) recommend an alert status should be triggered at a cyanobacterial cover in the range of 20-50%, taking action when the cover exceeds 50%.

While the attribute and freshwater objective focuses on cyanobacteria cover, the public health risks from detached scums will need to be addressed. The accumulations of algae that may detach are in part being managed by objectives that seek to limit algae cover. There are currently no attribute guidelines in relation to detached cyanobacteria accumulations on river banks. The public health risks of detached algal mats need to be addressed through good public information.

Table 2-3: NPS-FM bands and other guidelines for periphyton biomass, algal cover and *Phormidium*.

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
Algae biomass	Ecosystem health	MfE (2017a)	A - Rare blooms (details in document)	≤ 50 mg Chla/m^2	Exceeded no more than 8% of samples, min record length 3 years
			B - Occasional blooms	>50 mg and ≤ 120 mg Chla/m^2	Exceeded no more than 8% of samples, min record length 3 years
			C - Periodic short-duration nuisance blooms	>120 mg and ≤ 200 mg Chla/m^2	Exceeded no more than 8% of samples, min record length 3 years
			D - Regular and/or extended duration nuisance blooms	>200 mg Chla/m^2	Exceeded no more than 8% of samples, min record length 3 years
Algae cover	Recreation	Matheson *et al.* (2016)	Aesthetics/recreation	<30% PeriWCC	long-term annual maxima - average min 3 years
Algae cover	Ecosystem health	Matheson *et al.* (2016)	Ecological condition excellent	<20% PeriWCC	long-term annual maxima - average min 3 years
			Ecological condition good	<40% PeriWCC	
			Ecological condition fair	<55% PeriWCC	
			Ecological condition poor	≥55% PeriWCC	
Phormidium	Human health, recreation	MfE & MoH (2009)	Alert	<20% cover	Maximum

2.1.3 Macrophytes

Aquatic plants called macrophytes typically grow in low gradient, slow flowing, fine bed substrate lowland streams and rivers.

Under natural conditions macrophytes are an important habitat in lowland streams, as they provide stable habitat and shelter for aquatic organisms in soft sediment streams. Under unshaded and prolonged low-flow conditions macrophytes grow so prolifically that they can reach nuisance levels, and clog the stream channel. Macrophytes in high abundance can have a detrimental effect on ecological health by impacting instream dissolved oxygen levels through photosynthetic and respiration processes, by reducing flow conveyance, and by detrimentally affecting aesthetic and recreational values. In addition, consumption of inorganic carbon during photosynthesis results in changes to the equilibrium balance of carbonate/bi-carbonate/carbonic ions in the water and can lead to marked diurnal fluctuations in pH. This in turn leads to detrimental effects on aquatic organisms, and increases the toxicity of ammonia.

Matheson et al. (2016) provide instream macrophyte guidelines based on percent occupation of channel cross-sectional area/volume (CAV) or water surface area (SA). Thresholds based on volume of water column occupied are recommended as most suitable for protecting other stream life from effects of excessive plant abundance and for facilitating flow conveyance (Matheson et al., 2012). These guidelines relate to the values of ecological condition, flow conveyance, recreation and trout fishery-angling. Thresholds based on water surface area might be applied additionally as an attribute for aesthetics and recreation for floating-leaved species (Table 2-4).

Macrophyte assessments in HBRC State of the Environment monitoring includes both cross-sectional area/volume and water surface area cover. CAV was recommended as an attribute as it is the most critical factor in TANK lowland streams and covers the relevant values ecosystem health, flow conveyance and recreation.

Table 2-4: Discussed water quality values for macrophyte abundance.

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
Macrophytes volume (CAV)	Ecosystem health	Matheson *et al.* (2016)	Ecological condition / flow conveyance / recreation	≤ 50 % CAV	annual maxima
Macrophytes volume (CAV)	Trout fishery/ angling	Matheson *et al.* (2016)	Excellent trout fishery/angling	≤10 % CAV	annual maxima
			Good trout fishery/angling	≤20 % CAV	
			Fair trout fishery/angling	≤30 % CAV	
			Poor trout fishery/angling	>30 % CAV	
Macrophytes water surface area (SA)	Ecosystem health	Matheson *et al.* (2016)	Aesthetics/recreation	≤ 50 % SA	annual maxima

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
Macrophytes water surface area (SA)	Trout fishery/ angling	Matheson *et al.* (2016)	Excellent trout fishery/angling	≤5 % SA	annual maxima
			Good trout fishery/angling	≤10 % SA	
			Fair trout fishery/angling	≤20 % SA	
			Poor trout fishery/angling	>20 % SA	

2.1.4 Nutrients

Eutrophication is the term used to describe the enrichment of water bodies by inorganic plant nutrients such as nitrate or phosphate. Eutrophication may occur naturally over geological timescales, particularly in lakes, and in rivers eutrophication increases from upstream to downstream, but higher levels of enrichment are commonly the result of human activity. Land-use change and intensification often give rise to elevated levels of nitrogen and phosphorus, particularly in areas where appropriate farming practices are not followed. Nuisance periphyton growth can be managed by reducing or eliminating inputs of nitrogen and phosphorus from point-source discharges and/or diffuse sources such as discharges from land-use (Biggs, 2000).

Dissolved Inorganic Nitrogen (DIN) and Dissolved Reactive Phosphorus (DRP) are inorganic forms of the nutrients nitrogen (N) and phosphorus (P) respectively. N and P are the two key macronutrients required for growth of plants and algae, occurring in all living cells – for example being key elements in proteins and DNA. DIN includes nitrate, nitrite and ammonia. DRP includes phosphate. Although numerous other forms of nitrogen and phosphorus exist and are commonly referred to in the field of water quality (e.g. organic and particulate forms), it is the dissolved forms DIN and DRP that are most readily available for uptake by plants and are thus most relevant for assessing effects on nuisance plant growth in rivers. The terms total nitrogen (TN) and total phosphorus (TP) refer to the sum total of all forms of N and P respectively in a sample. TN and TP are most relevant for assessments in lakes and coastal waters. At sufficiently elevated concentrations, nitrate and ammonia forms of nitrogen have toxic effects on aquatic biota (and on humans in the case of nitrate). This effect is independent of their significance as plant nutrients (Norton, 2012).

Nitrogen (N) and phosphorus (P) are key 'growth limiting' nutrients that influence the growth rate and extent of algae (or periphyton) and aquatic plants. A deficit in the supply of one or both of these two nutrients often limits plant biomass development (Matheson et al., 2012). A nutrient limitation study was carried out to investigate if there was a key growth limiting nutrient in the Tūtaekurī and Ngaruroro rivers. As the identification of a limiting nutrient is only a snapshot in time, and limitation can change over time, the test was conducted 4 times over the course of two years. The results showed that nutrient limitation changed over time, and algal growth rates were predominantly co-limited in the Ngaruroro River and co-limited to N-limited in the Tūtaekurī River (Haidekker, 2016b). The Waitangi estuary, the receiving environment downstream of the three catchments Ngaruroro, Tūtaekurī and Karamū is also co-limited. Any increase of N or P being discharged to rivers in the upstream catchments risks increased algal growth rates and eutrophication of the estuary.

Nutrient guidelines discussed were from ANZECC (2000), RRMP (HBRC, 2006a) and Matheson *et al.* (2012), and (2016), summarised in Table 2-5. After discussing nutrient guidelines with the stakeholder group early in the TANK process, the National Policy Statement for Freshwater was subsequently amended (MfE, 2017a, MfE, 2018b). A draft technical guide to the periphyton attribute note became available in 2018 (MfE, 2018a). The guidelines that were agreed on by the TANK Group are consistent with recommended guidelines in the 2017 attribute note derived by models for setting nutrient criteria for hard bottom streams that could support conspicuous periphyton (and therefore does not apply to area 4, macrophyte dominated streams).

Table 2-5: DIN and DRP concentration guidelines related to algal biomass and cover.

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
DIN	Algal growth - recreation <30% algae cover	Matheson *et al.* (2016)	Very low risk	<0.05 mg/L	long-term mean, all flows
			Low risk	0.05 to <0.15 mg/L	
			Moderate risk	0.15 to < 0.3 mg/L	
			High risk	>0.3 mg/L	
	Algal growth - benthic biodiversity	Biggs (2000)	Chl*a* ≤50 mg/m^2	0.02 mg/L	for 20d accrual period
				0.01 mg/L	for 30d accrual period
	Algal growth - angling interest	Biggs (2000)	Chl*a* ≤120 mg/m^2 filamentous Chl*a* ≤200 mg/m^{2}diatoms	0.295 mg/L	for 20d accrual period
				0.075 mg/L	for 30d accrual period
	statistical value, 80th percentile of lowland rivers	ANZECC (2000)	statistical default guideline for lowland rivers	0.444 mg/L	long-term median, all flows
DRP	Algal growth - recreation <30% algae cover	Matheson *et al.* (2016)	Very low risk	<0.003 mg/L	long-term mean, all flows
			Low risk	0.003 to <0.006 mg/L	
			Moderate risk	0.006 to < 0.015 mg/L	
			High risk	>0.015 mg/L	

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
	Algal growth - benthic biodiversity	Biggs (2000)	Chl*a* ≤50 mg/m^2	0.001 mg/L	for 20d accrual period
				0.001 mg/L	for 30d accrual period
	Algal growth - angling interest	Biggs (2000)	Chl*a* ≤120 mg/m^2 filamentous Chla ≤200 mg/m^{2}diatoms	0.026 mg/L	for 20d accrual period
				0.006 mg/L	for 30d accrual period
	statistical value, 80th percentile of lowland rivers	ANZECC (2000)	Statistical default guideline for lowland rivers	0.01 mg/L	long-term median, all flows
	Algal growth, instream habitat	HBRC (2006b) RRMP		0.015 mg/L	long-term median, flows < median

2.1.5 Nitrate and ammonia toxicity

The NPS-FM requires councils to set a freshwater objective for nitrate and ammonia in all rivers.

DIN, as discussed in Chapter 2.1.4, includes nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N) and ammoniacal-nitrogen (NH_4-N). Nitrate-nitrogen is the dominant component of DIN in areas not directly affected by point-source discharges and in catchments without large areas of wetlands with anoxic soils. Generally, nitrate concentrations are managed at considerably lower than toxic levels to achieve periphyton objectives using the DIN attribute.

Nitrate and ammonia are toxicants that can cause lethal or sub-lethal (e.g. reducing growth rates or reproductive success) effects to aquatic species. These effects can occur as a result of short-term (hours to days) or long-term (weeks, months, years) exposure to nitrate or ammonia.

In the Guide to Attributes report (MfE, 2018b) toxicity attributes of the NPS-FM are explained in the following way:

> The NPS-FM defines nitrate and ammonia toxicity attribute states based on concentrations that protect a specific percentage of test species from long-term exposure to nitrate. The national bottom line is set at nitrate concentrations that provide protection from effects of long-term exposure for 80 per cent of species. The higher attribute states provide for protection from effects of long-term exposure for 95 per cent to 99 per cent of species. All of the Freshwater NPS nitrate toxicity attribute states protect 100 per cent of test species from effects of short-term exposure.

The concentrations for these attributes are derived from observed effects from long-term exposure to nitrate in studies on 22 freshwater aquatic species (Hickey, 2013), and to ammonia in studies on 19 freshwater aquatic species (Hickey, 2014) (unpubl.) as cited in the NPS-FM (MfE, 2017a)). The first set of attribute state thresholds (i.e. median concentration) are set at the 'No Observed Effect Concentration' (NOEC) for each level of species protection. The second set of attribute state thresholds (i.e. annual maximum and 95th percentile) are set at the 'Threshold Effect Concentration' (TEC) for each level of species protection. TEC is the geometric mean of NOEC and the lowest observed effect concentration (LOEC). The TEC value is below the lowest statistically significant effect concentration[1].

Each set of thresholds (Table 2-6) is associated with a particular sample statistic to reflect different timescales of effect:

- NOEC and a sample median manages exposure under 'average' conditions in nitrate and ammonia concentrations.
- TEC and a 95th percentile manages exposure during seasonal peaks in nitrate concentrations.
- TEC and a maximum manage exposure during critical events and daily or seasonal peaks in ammonia concentrations.

The toxicant effects of ammonia come from the un-ionised form, while the numeric attribute states are defined for (total) ammoniacal nitrogen. Temperature and pH have a significant effect on the fraction of un-ionised ammonia and its toxicity, so the numeric attribute -, and therefore freshwater objectives, are defined for a pH of 8 and temperature of 20°C.

Table 2-6: NPS-FM-NOF bands for nitrate and ammonia toxicity.

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
Ammonia	Toxicity	MfE (2017a)	A - 99% spec protection, no effect on any species	≤0.03 mg/L / ≤0.05 mg/L	annual median / annual max
			B - 95% spec protection, starts impact on 5% most sensitive spec	≤0.24 mg/L / ≤0.4 mg/L	
			C - 80% spec protection, reduced survival of most sensitive species	≤1.3 mg/L / ≤2.2 mg/L	
			D - Starts approaching acute impact level for sensitive species	>1.3 mg/L / >2.2 mg/L	
Nitrate	Toxicity	MfE (2017a)	A - unlikely to be effect on any species, high conservation value	≤1 mg/L / ≤1.5 mg/L	annual median / 95th %ile
			B - some growth effects on 5% most sensitive spec	≤2.4 mg/L / ≤3.5 mg/L	

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[1] Taken from https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/derivation-of-indicative-ammoniacal.pdf

Attribute	Value	Source	Guideline context / band / level of protection	Numeric value	Application
			C - growth effects on up to 20% species, no acute effects	≤6.9 mg/L / ≤9.8 mg/L	
			D - Impact on growth of multiple species, approaches acute impact level	>6.9 mg/L / >9.8 mg/L	

2.1.6 Temperature

Temperature is important for stream ecology, because it affects instream processes such as metabolism, organic matter decomposition, and the solubility of gases such as oxygen. Temperature also directly affects stream biota by influencing cellular processes such as development, survival, reproductive success and behaviour.

Unlike mammals, which thermoregulate, aquatic organisms cannot keep their bodies at a constant temperature. Instead, their temperature varies with the environment (thermoconforming). Consequently, temperature exerts a key role on physiological processes in aquatic organisms. The most significant instream temperature effect on aquatic organisms is usually summer high water temperatures.

Different species can tolerate different temperature ranges. 'Lethal limits' seriously stress species and they may die, but 'sub-lethal limits', affect feeding and species growth (Olsen et al., 2011). The management of water temperatures needs to consider more than just the critical lethal limit, but should integrate the thermal requirements of all life stages of aquatic organisms.

The effect of water temperature on species has generally been tested under constant temperatures in laboratory experiments. However, stream temperatures fluctuate daily, with afternoon maxima and night minima. To account for the temperature varying over a daily cycle in rivers, Cox and Rutherford (2000) showed that the critical temperatures affecting species were best expressed as the value mid-way between the daily maximum and mean temperatures. This Cox-Rutherford Index (CRI) permits the application of (constant) temperature criteria to temperature regimes varying over a diel cycle in rivers. Temperature thresholds proposed for the National Objectives Framework (Davies-Colley et al., 2013) are based on the Cox-Rutherford Index (CRI).

Davies-Colley et al. (2013) proposed temperature thresholds for discussion for the National Objectives Framework. Three approaches are suggested: 1- Temperature regime thresholds for rivers and streams in the 'Maritime' regions of New Zealand, 2 - thresholds for 'Eastern Dry' regions, and 3 - limits for temperature increments to site-specific reference condition.

The two temperature regime thresholds proposed for New Zealand account for different climatic conditions: The 'Maritime' regions and the 'Eastern Dry' regions. The latter applies to Hawke's Bay, and has thresholds that are 1°C warmer than the Maritime regions (Table 2-7).

Table 2-7: Proposed NOF limits for temperature regime in rivers and streams in 'Eastern Dry' regions of New Zealand. The temperature regime is calculated as the summer period measurement of the Cox-Rutherford Index (CRI), averaged over the five hottest days (from inspection of a continuous temperature record). Table from Davies-Colley et al. (2013)

Attribute State Temperature Regime	Numeric Attribute State CRI (°C)	Narrative Attribute State
A	≤ 19°C	No thermal stress on any aquatic organisms that are present at matched (near-pristine) reference sites.
B	>19 to ≤ 21°C	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.
C	>21 to ≤25°C	Some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish.
D	>25°C	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.

The NOF threshold document suggests that should the temperature thresholds as proposed for the maritime or Eastern Dry Regions (Table 2-7) put streams and rivers with good ecological health into the C (slightly degraded) or D (significantly degraded) category, a site-specific approach to temperature thresholds may be applied (temperature increments to reference site) (Table 2-8).

Continuous temperature recordings from 2013 had a CRI of 20.7°C in the Ngaruroro at Kuripapango and 20.1°C in the Tūtaekurī at Lawrence Hut, placing the near-pristine sites into the NOF B band. In summer 2016/17 the CRI was 21.5°C and 21°C at the two sites respectively, meaning the Ngaruroro at Kuripapango was falling into the C band (Table 2-10). Because the reference sites would be in the B/C bands for temperature, it seems more reasonable to use the temperature increments to reference condition method instead of temperature thresholds provided for the Eastern Dry Region.

Table 2-8: Proposed NOF limits for temperature increment in rivers and streams. Limits can be applied on a site-specific basis in New Zealand at council's discretion if sufficient supporting data is available. Temperature regime thresholds are calculated as the summer period measurement of the Cox-Rutherford Index (CRI), averaged over the five (5) hottest days (from inspection of a continuous temperature record). Table from Davies-Colley et al. (2013).

Attribute State Temperature Regime	Numeric Attribute State CRI (°C)	Narrative Attribute State
A	≤ 1°C increment compared to reference site	No thermal stress on any aquatic organisms that are present at matched (near-pristine) reference sites.
B	≤ 2°C increment compared to reference site	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.
C	≤ 3°C increment compared to reference site	Some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish.
D	> 3°C increment compared to reference site	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.

Davies-Colley et al. (2013) recommend using one set of thresholds as in Table 2-7 and Table 2-8 for both upland and lowland rivers after considering that the thermal inertia provided by forested catchments under reference condition would mitigate the effects of a decrease in altitude. Thermal regimes of many lowland rivers are elevated as a result of widespread deforestation and are not representative of reference site conditions. Davies-Colley et al. (2013) suggest developing separate upland and lowland temperature thresholds should be a discussion point, but a preference is given to using a single framework until more information on reference condition is available.

For the development of TANK temperature thresholds this means that any site in near pristine condition could serve as reference site for a single set of thresholds for temperature bands in the TANK catchments as an interim, until more reference condition data is available.

Ngaruroro at Kuripapango and Tūtaekurī at Lawrence Hut are near-pristine reference sites in the TANK upper catchments. As stated above, one set of thresholds are currently recommended until more knowledge on temperature reference conditions in lowland areas is gained. Only these two reference sites are available for the TANK area, which means all other sites will have to be compared to these two pristine upland sites. This seems to be the best available approach, but bears the risk of not being appropriate reference sites for hill country tributaries, lowland streams or even the lower mainstems, with braided gravel beds. It might mean setting unrealistic temperature thresholds that will be impossible to meet given the naturally hot and dry climate.

The continuous temperature data from the Ngaruroro at Kuripapango and the Tūtaekurī at Lawrence Hut (upstream catchments predominantly in native vegetation/DOC reserve), were used as reference sites, summer CRI calculated, and bands developed using the temperature increments as in Table 2-8. These temperature thresholds were compared to the proposed temperature thresholds in the NOF discussion document for the Eastern Dry Region (Table 2-9).

Table 2-9: Comparison between Eastern Dry Region temperature thresholds and temperature increments compared to reference. Average reference temperature Ngaruroro at Kuripapango: 21.1°C and Tūtaekurī at Lawrence Hut 20.7°C. This was rounded to 21°C reference condition temperatures.

Reference	Increment compared to reference site	Thresholds compared to reference in TANK (= 21°C)	Thresholds Eastern Dry Region
A	≤ 1°C	≤ 22°C	≤ 19°C
B	≤ 2°C	≤ 23°C	≤ 21°C
C	≤ 3°C	≤ 24°C	≤ 25°C
D	> 3°C	> 24°C	> 25°C

Based on the reference (CRI) temperature of 21°C (21.1°C at Kuripapango and 20.7°C at Lawrence Hut) increments for bands compared to reference condition were calculated. The band A/B and B/C thresholds are 2 to 3°C higher than the thresholds for the Eastern Dry Region. On the other hand, the bottom line C/D threshold is lower, with 24°C being 3°C more than reference, whereas the Eastern Dry Region defines 25°C as the C/D band.

Summer CRI temperatures for each of the SOE sites where temperature loggers were deployed and the corresponding proposed NOF bands are summarised in Table 2-10. The results of summer CRI temperature regimes in lowland streams in the Heretaunga Plains (TANK areas 4a and 4c) range from band A with 17.4^{o}C to band D with 24.7^{o}C. The shading is minimal at and upstream of most sites, but groundwater upwelling may be the reason for cool water temperature at some sites. There is no guidance on how to account for this effect in lowland areas and more work needs to be done to establish reference conditions with regards to this aspect.

Table 2-10: Summer temperatures from continuous measurements expressed as Cox-Rutherford-Index (CRI) for TANK sites and the corresponding bands for Eastern Dry Climates and temperature increments from reference condition. Reference sites are shaded grey.

	TANK area	CRI (°C)						Average CRI	Band Eastern Dry Climates	Band Temperature Increments
		2013	2014	2015	2016	2017	2018			
Ngaruroro at Kuripapango	**1a**	**20.7**				**21.5**		**21.1**	**C**	**A**
Tūtaekurī at Lawrence Hut	**1b**	**20.1**				**21.0**	**21.1**	**20.7**	**B**	**A**
Ngaruroro at Whanawhana	2a			22.2	23.01	21.6	*(20.5*)*	22.3	C	B
Ngaruroro d/s HB Dairies	2a				23.5			23.5	C	C
Ngaruroro at Fernhill	2a	22.5		22.5				22.5	C	B
Tūtaekurī at Dartmoor	2b	23.3				24.6		24.0	C	C
Taruarau	3a	20.7						20.7	B	A
Poporangi-Ohara	3a					23.1		23.1	C	C
Mangatutu	3b					22.3		22.3	C	B
Mangaone	3b	24.6				23.8		24.2	C	D
Waitio	4a		17.2			17.6		17.4	A	A
Tūtaekurī-Waimate	4a		19			20.3		19.7	B	A
Clive	4c					22.1		22.1	C	B
Herehere	4c					21.8	24.9	23.4	C	C
Karewarewa	4c					23.7	25.6	24.7	C	D
Awanui	4c					23	25.3	24.2	C	D

*logger deployed 17 Feb 2018 and therefore likely to have missed the hottest summer days, these occurred earlier at other sites.

Thresholds based on temperature increments compared to reference conditions were presented to the TANK Group for discussion. These were based only on the two reference sites in the upper Tūtaekurī (at Lawrence Hut) and Ngaruroro (at Kuripapango). The TANK Group agreed on the objective for the plan change to be Band A for the upper Ngaruroro and Tūtaekurī (≤ 22°C) and Band B for all other areas in the TANK catchments (≤ 23°C) (Appendix A).

The reviewer of this report emphasised the limitations of this approach given the lack of scientific knowledge for reference temperature in small hill country streams, lowland streams and wide, braided rivers at the bottom of the catchments. He highlighted that using upland reference sites to set lowland temperature limits is likely to result in unachievable targets.

Other gaps and limitations to the proposed thresholds are outlined in the NOF discussion document (Davies-Colley et al., 2013):

> '… We note that the limits were not derived using a rigorous species tolerance approach for resident species. Limits would be improved by derivation of suitable sub-lethal chronic endpoints (e.g., T_{opt}) and evaluation of reference sites for native species, particularly for macroinvertebrates. The effects of diel variability in temperature have only been quantified for a limited number of macroinvertebrate species and diel temperature ranges (the CRI). Research is required to test and extend this work to other species and for comparison to the proposed limits.'

In view of the reviewer's comments and additionally the gaps and limitations with regards to species specific knowledge on temperature thresholds that were discussed on the NOF proposed thresholds document, it was no longer seen as justifiable to use the thresholds as presented to the TANK Group. The recommendation was to use the temperature increments (Table 2-8) as limits in the plan change, until science supports a more robust approach to develop absolute temperature limits for the different stream and river types. To align the objectives with the TANK Group decision, the agreed bands were transferred from the proposed temperature thresholds for the Eastern Dry Regions to the corresponding increment limits: Band A for the upper Ngaruroro and Tūtaekurī (≤ 1°C increment compared to reference state; instead of ≤ 22°C) and Band B for all other areas in the TANK catchments (≤ 2°C increment compared to reference state; instead of ≤ 23°C). Using upland reference sites to assign temperature limits for lowland waterways is not optimal. The grades based on existing monitoring data, however, seem reasonable based on the author's understanding of existing state, and support these limits as a pragmatic framework to use in the absence of better reference sites (see Table 2-10 discussion). However, the 22°C and 23°C thresholds for the respective management areas are retained in Schedule 2, which does not have a regulatory function, but is an optional provision, which provides additional direction for the monitoring and research efforts of the Council.

The reviewer also noted that in the hot and dry climate the reference condition might already stress sensitive aquatic life, and for example a > 1 °C increment in temperature might result in further thermal stress. He suggests that the narrative attribute state of Table 2-8 from the original document by Davies-Colley et al. (2013) should then be read as: < 1 °C will result in no further thermal stress compared to that expected at the reference site, < 2 °C increment would result in minor further thermal stress compared to that the reference site, etc. The wording is changed accordingly in Table 2-11.

Table 2-11 Proposed temperature increment thresholds Schedule 1

TANK Surface WQ Area	Attribute state	Numeric state (CRI °C)	Narrative Attribute State
Upper Ngaruroro and Upper Tūtaekurī Rivers	Band A	≤ 1°C increment compared to reference state	No further thermal stress to that expected on any aquatic organisms that are present at matched (near-pristine) reference sites.
Lower Ngaruroro and Lower Tūtaekurī Rivers	Band B	≤ 2°C increment compared to reference state	Minor further thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.

Ngaruroro and Tūtaekurī Tributaries	Band B	≤ 2°C increment compared to reference state	Minor further thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.
Lowland tributaries	Band B	≤ 2°C increment compared to reference state	Minor further thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.

2.1.7 Dissolved Oxygen

Dissolved oxygen (DO) is an important component in the life-supporting capacity of freshwater ecosystems. Humans absorb oxygen from air through their lungs, while aquatic organisms absorb oxygen from water through their gills/skin. Fish, invertebrates and other organisms are stressed when insufficient oxygen is dissolved in water.

Various elements of aquatic systems either consume and/or produce oxygen. Plants and algae growing in the water produce oxygen as a by-product of photosynthesis. This supplements oxygen passively diffusing into the water from the atmosphere or being infused by turbulence or aeration in steeper or fast flowing streams, a process known as re-aeration. However, plants and algae also use oxygen when they respire, as do animals, fungus and bacteria living in the water. The breakdown of organic matter by aerobic micro-organisms also consumes oxygen and is termed the 'biological oxygen demand' (BOD). This process also occurs in the sediments and is termed the 'sediment oxygen demand' (SOD).

DO varies between day and night in a similar way to water temperature: DO increases during daytime due to photosynthesis, and decreases at night since respiration continues but the photosynthesis of aquatic plants ceases. In un-shaded streams with high nutrient inputs, excessive growth of plants and algae results in extremely high dissolved oxygen levels during the day, then extremely low dissolved oxygen levels during the night or early morning, when these plants and algae consume more oxygen than the waterway is capable of supplying. The low dissolved oxygen conditions mean there is little oxygen for fish and other organisms to use.

Three main processes are likely to cause low dissolved oxygen conditions:

(1) Aquatic plant and algal respiration during the night

(2) Oxygen consumption by microbes that break down organic matter

(3) Low reaeration of oxygen from the atmosphere, which may occur in low gradient streams with reduced flow and/or without flow turbulence typically provided by logs, roots, plants or variable stream banks in lowland streams.

Therefore low gradient streams with a soft bottom and aquatic plant growth are most at risk to have low DO conditions. The relationship between stream flow and DO in the low-gradient streams of the Heretaunga Plains was analysed by Wilding (2015) and discussed separately with the TANK Group.

A waterway with DO consistently below 5.0 mg/L is unable to support sensitive species and the ecological integrity of these systems will be compromised. DO greater than 8.0 mg/L is typically capable of supporting the full range of aquatic organisms (Davies-Colley et al., 2013).

Colder water can hold more oxygen than warmer water. When water temperature is greater than 27°C it cannot hold more than 8.0 mg/L of oxygen. Unshaded systems that overheat during the day can also be depleted of oxygen.

Water temperature increases detrimentally affect aquatic organisms like fish or invertebrates in two ways. As water temperature increases, oxygen requirements also increase as they become more active (Elliott, 1994). At the same time, increasing water temperatures decrease the oxygen-carrying capacity of water.

ANZECC (1992) guidelines recommend minimum DO concentrations of 6 mg/L and 80% saturation. Hay et al. (2006) suggest these limits should be seen as short-term exposure levels (i.e. occurring only for a few days), as data suggest that long-term exposure to DO levels of 6 mg/L can impair the growth of salmoniids, including trout (CCME, 1997).

In New Zealand, the Resource Management Act 1991 (MfE, 1991) proposes a default standard of 80% DO saturation, which has been adopted widely across the country. DO criteria for effects on aquatic organisms are primarily expressed as concentration (DO mg/L) rather than saturation (% DO), based on the strong observed relationship between DO concentrations and ecological response (Franklin, 2013). This provides greater protection at higher temperatures without the need for a temperature dependent threshold scale. The proportion of dissolved oxygen (%DO) in water changes with temperature while the concentration (DO mg/L) does not. Additionally, the oxygen demand of aquatic organisms like fish and macroinvertebrates increases with higher temperatures while the DO saturation decreases, which seems counterintuitive to use as a standard for ecosystem protection purposes.

The DO attribute states are defined in the Freshwater NPS by two expressions of DO minima; the lowest 7-day mean of daily minima (the '7-day mean minimum') and the lowest daily minimum (the '1-day minimum'). The DO attributes must be used to set freshwater objectives for rivers downstream of point sources. Councils must decide on the desired level of protection for the aquatic ecosystem and define freshwater objectives using the appropriate DO concentrations for both sample statistics (i.e., 7-day mean minimum and the 1-day minimum) (Table 2-12). Freshwater objectives should be set in the same attribute state for both statistics.

The DO attributes must be used to set freshwater objectives for rivers downstream of point sources, though management may focus on both point and non-point sources to achieve the freshwater objectives. The TANK Group discussed the DO attribute for the TANK catchments independent of point-source discharges, in relation to ecosystem health and risk for aquatic organisms from low DO.

Table 2-12: NPS-FM NOF bands for dissolved oxygen for ecosystem health. 7-day mean minimum and 1-day minimum DO attribute of the National Objective Framework ((MfE, 2018b, MfE, 2017a)).

Attribute	**Value**	**Source**	**Guideline context / band / level of protection**	**Numeric value**	**Application**
Dissolved oxygen	Ecosystem Health	MfE (2017a)	A: No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.	≥8.0 mg/L/ ≥7.5 mg/L	7-day mean min / 1-day min
			B: Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.	≥7.0 and <8.0 mg/L / ≥5.0 and <7.5 mg/L	7-day mean min / 1-day min
			C: Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.	≥5.0 and <7.0 mg/L / ≥4.0 and <5.0 mg/L	7-day mean min / 1-day min
			D: Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.	<5.0 mg/L / <4.0 mg/L	7-day mean min / 1-day min

2.1.8 Macroinvertebrates

Macroinvertebrate communities are commonly used as an indicator of water quality and ecosystem health. The macroinvertebrate community of a stream adjusts to conditions in the aquatic environment, including naturally induced changes and stressors affecting ecosystem health. The macroinvertebrates collected at a site are exposed to changes in conditions at that site for periods of months, to a year or even several years, depending on their life cycle. Macroinvertebrate community composition changes as sensitive species experiencing stress are lost, which leads to a community dominated by more tolerant species.

The Macroinvertebrate Community Index (MCI) was developed by Stark (1985) as a biomonitoring tool to assess stream health based on the presence or absence of certain invertebrate species. A higher MCI score indicates more pollution 'intolerant' or sensitive species are present (Table 2-13). The MCI of a site can be used to assess the likely level of ecosystem degradation. Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) larvae (called EPT taxa) are sensitive to pollution, so MCI scores are high when they are present. Community composition metrics like the proportion of EPT taxa present at a site can also be used as an indicator of stream health complementary to the MCI.

The MCI summarises the complexity of stream health in a single numeric value that can be related to a wide range of factors. It provides a long-term and integrated view of water quality. The MCI is the most commonly used indicator of macroinvertebrate community health in large-scale monitoring and reporting in New Zealand, such as State of the Environment monitoring and reporting undertaken by regional councils and TLAs.

Table 2-13: MCI quality classes as defined by Stark and Maxted (2007).

MCI	Quality class
≥120	Excellent quality, clean water
100-119	Good quality, possible mild pollution
80 – 99	Fair quality, probable moderate pollution
< 80	Poor quality, probable severe pollution

Both human activities and natural changes such as drought and floods, or natural variations in stream bed substrate type and water temperature may affect macroinvertebrate communities. National-scale predictive modelling has illustrated that MCI scores can be strongly influenced by natural environmental gradients. MCI scores can vary from 90 to 150 at near pristine reference sites across New Zealand (Clapcott et al., 2013). To be able to account for the natural variability between river types in Hawke's Bay, HBRC commissioned Cawthon Institute to develop a regionally-optimised predictive model of MCI scores to develop robust indicator states for MCI in Hawke's Bay streams. The distributions of predicted MCI scores were used to recommend MCI bands for FENZ classes present in the Hawke's Bay Region (Clapcott and Goodwin, 2018). Weather dependent field work was completed later than expected and the results only became available towards the end of the plan change process. There was no time left to allow for a discussion with the TANK Group on the predicted bands or to revisit the discussions on MCI objectives already set by the Group.

Table 2-14 is a comparison between the MCI management bands as modelled for Hawke's Bay and the TANK objectives with their respective bands as set by the TANK Group. For the upper Ngaruroro and Tūtaekurī (Area 1) the TANK Group decided on an MCI objective of greater than 120, indicating excellent water quality as defined by the categories in Stark and Maxted (2007). An MCI of 120 would fall into the B-Band of the modelled management bands for the same FENZ class. Nevertheless the MCI at the reference sites are at or near an MCI of 130, and the current state is protected from degradation, which de facto means Ngaruroro at Kuripapango and Tūtaekurī at Lawrence Hut are in the (modelled) A-Band with an MCI of 130. For areas 2 (lower main stems) and 3 (hill country tributaries), the TANK group agreed on an objective to achieve an MCI ≥100 indicating good water quality. This corresponds to the B-Band of the modelled regional management bands, but the TANK objective sets a slightly higher objective for the hill country tributaries where the modelled B/C threshold is 90. In area 4, lowland streams, the TANK Group set the objective at an MCI of 90, which reflected the desire to manage towards an achievable state (fair water quality), but better than at the boundary to poor water quality of MCI<80 – or the equivalent of the bottom line (D-Band).

Table 2-14: Modelled Hawke's Bay management bands for MCI in comparison with TANK MCI objectives.

TANK surface water quality areas	FENZ Class	Modelled regional management bands			TANK objective	TANK Band
		A/B	B/C	C/D		
1	C7C10	130	110	90	≥120	A
1	C*(other)	130	110	90		
1	G	130	110	90		
1	H	130	110	90		
2	C4	110	90	80	≥100	B
2 / 3	C6	120	100	80	≥100	B
3	C1C5	120	100	80		
3	C8C9	120	100	80		
4	A	100	80	80	≥90	B/C

2.1.9 Pathogens - *Escherichia coli*

During the stakeholder group process the national direction on bacterial guidelines were under revision and changed multiple times, which made the discussion more complex and time consuming. Results and discussions on *E. coli* thresholds changed over time (slides and minutes from different meetings), but were being updated. The most recent definition of the attribute became available in 2017 through the guide to attributes of the NPS-FM (MfE, 2018b).

> The *Escherichia coli* (*E. coli*) attribute states define *E. coli* concentrations where different percentages of the population are at risk of *Campylobacter* infection through ingestion of water during recreation activities. The *E. coli* attribute describes different statistical measures of the distribution of *E. coli* concentrations, and the associated risk of *Campylobacter* infection through ingestion of water during recreation activities (McBride, 2012); (MfE and MoH, 2003).
>
> Each of the statistical measures are:
>
> - percentage of exceedances greater than 540 cfu/100ml: This measure indicates how often the level of *E. coli* exceeds the acceptable threshold for swimming
> - percentage of exceedances greater than 260 cfu/100ml: This measure indicates how often the *E. coli* exceeds the point where additional monitoring is required
> - median: The mid-point of *E. coli* levels

- 95th percentile: an indication of the top of the range of *E. coli* levels within the distribution.

The thresholds of what has been considered an acceptable level of *E. coli* (discussed in the NPS-FM-NOF document) are based on a ‘quantitative microbial health risk assessment’ (QMRA) that assessed what the corresponding risk of *Campylobacter* infection would be for different concentrations of *E. coli*.

Infection risk profiles have been developed to relate *E. coli* levels and the proportion of population at risk of *Campylobacter* infection for activities likely to involve full immersion such as swimming or white water rafting (McBride, 2012); (MfE and MoH, 2003).

The *E. coli* attribute table has five categories, or attribute states (i.e. A, B, C, D and E) (Table 2-15). Each attribute state has four criteria, or ‘statistical tests’, that need to be satisfied for water quality to be in that attribute state. Higher attribute states provide lower levels of infection risk for each activity type. All four criteria are necessary to establish an attribute state. If one or more criteria can’t be satisfied, a lower attribute state must apply.
For example, for water quality to be in the A state, it must:

- not exceed 540 cfu/100ml more than 5% of the time
- not exceed 260 cfu/100ml more than 20% of the time
- have a median of ≤130 cfu/100ml
- have a 95th percentile of ≤540 cfu/100ml.

If any of those criteria are not satisfied, water quality is in a lower state (eg, B, or lower, as long as all criteria can be satisfied). Note there is an overlap in the ‘exceedances over 260 *cfu*/100ml’ test between states B (20-30% exceedance) and C (20-34%). This overlap occurs because of an overlap in the underlying distribution used to set the attribute states. For example, if a site satisfied all of the other tests for B and had a 260 exceedance of 29% it would still be band B. If one of the other tests did not meet the band B criteria it would drop down to band C.

When categorising individual rivers or lakes using the *E. coli* attribute, the 95th percentile criteria may not apply if the council considers there is insufficient monitoring data to establish a precise 95th percentile. This is to acknowledge that monitoring data at this scale may be limited, and may not be sufficient to model the 95th percentile precisely.

Table 2-15: NPS-FM-NOF bands for *E. coli* attribute, for the compulsory value human health for recreation.

Freshwater Body Type	Lakes and rivers				
Attribute	*Escherichia coli (E. coli)*				
Attribute Unit	*E. coli*/100 mL (number of *E. coli* per hundred millilitres)				
Attribute State	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100ml	**% exceedances over 260 cfu/100ml**	**Median concentration (cfu/100ml)**	**95th percentile of *E. coli*/100 ml**	**Description of risk of *Campylobacter* infection (based on *E. coli* indicator)**
A (Blue)	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%*
B (Green)	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%*
C (Yellow)	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%*
D (Orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%*
E (Red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >7%*

*The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

Note: The attribute state should be determined by using a minimum of 60 samples over a maximum of 5 years, collected on a regular basis regardless of weather and flow conditions. However, where a sample has been missed due to adverse weather or error, attribute state may be determined using samples over a longer timeframe.

The attribute state must be determined by satisfying all numeric attribute states.

2.1.10 Other guidelines

Schedule 1 Freshwater Quality Objectives in PC9 (Appendix B), provides additional attributes and thresholds not discussed with the TANK Group, and for which not enough data was available to discuss current state, objectives and management implications.

It is recommended that provisions for pH, BOD (a measure of oxygen demand), heavy metals and metalloids, pesticides and organic contaminants, radioactive contaminants are included. Whilst there is little current state information or information about relevant guidelines for the identified values for these attributes they are particularly relevant for managing point source discharges in relation to their impact on freshwater values.

The 95% protection level used for assessing the effects of point source discharges on aquatic ecosystem health applies to ‘slightly to moderately disturbed’ ecosystems, and could be adopted as the default limit for waters to be managed for aquatic ecosystem health in the TANK tributaries and lower mainstem river. The ANZECC (2000) guidelines recommend the use of a higher (99%) protection level as the default trigger values for ecosystems with high conservation values. The ANZECC (2000) guidelines also recognise that it can be appropriate, depending on the state of the ecosystem, the management goals and in consultation with the community, to apply less stringent protection levels (90% or 80%), as intermediate targets for water quality improvement.

While it is expected that this level of performance is achievable for discharge activities, there is insufficient data about current discharge performance to be certain about costs associated with retrofitting discharge treatment for existing discharges to meet this standard.

In relation to heavy metal and other contaminants that could be present in stormwater, new policies for managing stormwater legacy issues aim to meet a protection level of 80th percentile level of species protection by 2023 and a 95th percentile protection level by 2040 for stormwater discharges. This regime reflects the challenges of managing urban stormwater and the significant costs associated with improving infrastructure.

2.2 Supporting information to identify issues and to set objectives

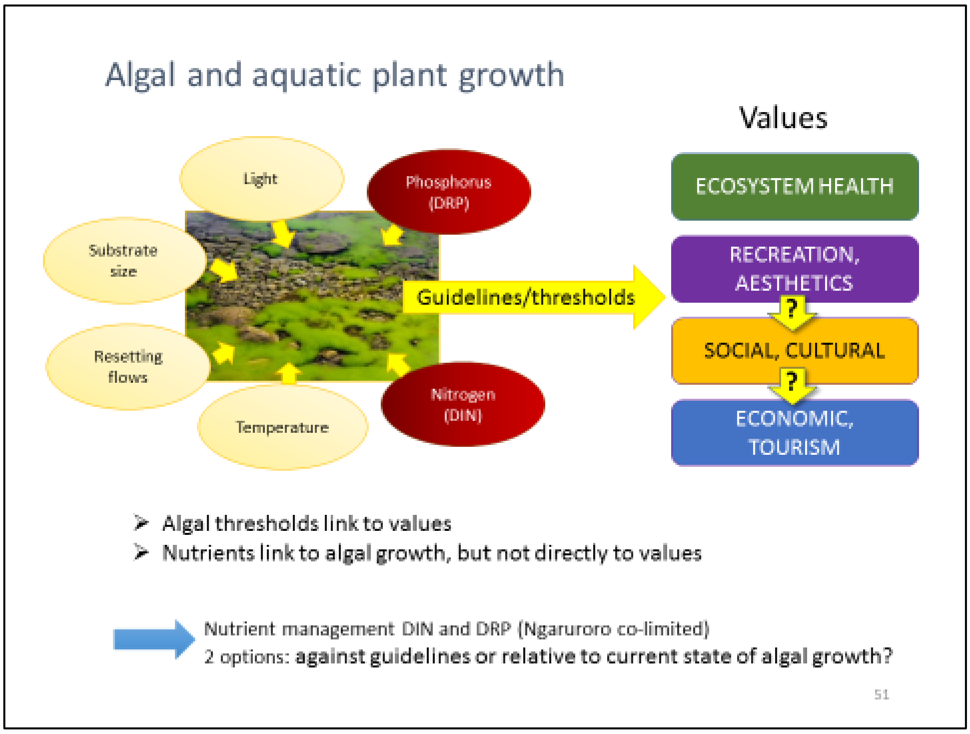
The previous chapter outlines the information provided to the TANK Group on compulsory attributes, and available water quality guidelines that could be used as attributes, and how they indicate the protection level of values. The next step was to provide the TANK Group with enough information to help them set objectives to protect the values the Group identified earlier, and to understand attribute interactions in an ecosystem and expected outcomes of management actions. In the following chapter information that was provided is listed with some example slides. This information is not in the order it was provided because the information was provided in an iterative manner. The following 'information packages' were discussed with the TANK Group:

1. Functional relationships and issues
    - Interactions of environmental factors and ecological outcomes / outcomes for values
    - Identifying issues
    - Managing attributes in different ecosystems (lowland vs hill country), different management options
    - Managing attributes in functional groups or common pathways
2. Managing attributes in relation to local or downstream values in receiving environments
3. Setting priorities

2.2.1 Information on attributes and values relationships

To facilitate informed decision making on objective / limit / target setting, information on key functional interactions between water quality variables (attributes), ecological functions and the relationship to values were provided. Management options and potential benefits also were discussed. The following examples were key topics. It is not an exhaustive list of the information provided. The TANK meeting records on the HBRC website provide full information that has been provided to the TANK Group.

For the hard–bottomed, algal dominated streams and rivers in the Tūtaekurī and Ngaruroro catchments, the key factors for algal growth were discussed, and the cause-and effect chain of nutrient concentrations, algal growth, and affected values (Figure 2-1). A targeted study also was carried out in 2013 and 2014 to understand nutrient limitation in the two catchments (Haidekker, 2016b). Algal growth rates are predominantly co-limited in the Ngaruroro River and co-limited to N-limited in the Tūtaekurī River. Four repeat tests over two years indicated that nutrient limitation was not a stable condition but changed over time: For example nutrient limitation in the Ngaruroro River at Fernhill switched between co-, N- and P-limitation. The Waitangi estuary is predominantly co-limited, which means any increase of N or P being discharged to rivers in the upstream catchments risks increased eutrophication of the estuary. Managing both nutrients is key to managing algal growth in these rivers.



Algal and aquatic plant growth

Light

Phosphorus (DRP)

Substrate size

Resetting flows

Temperature

Nitrogen (DIN)

Guidelines/thresholds

Values

ECOSYSTEM HEALTH

RECREATION, AESTHETICS

?

SOCIAL, CULTURAL

?

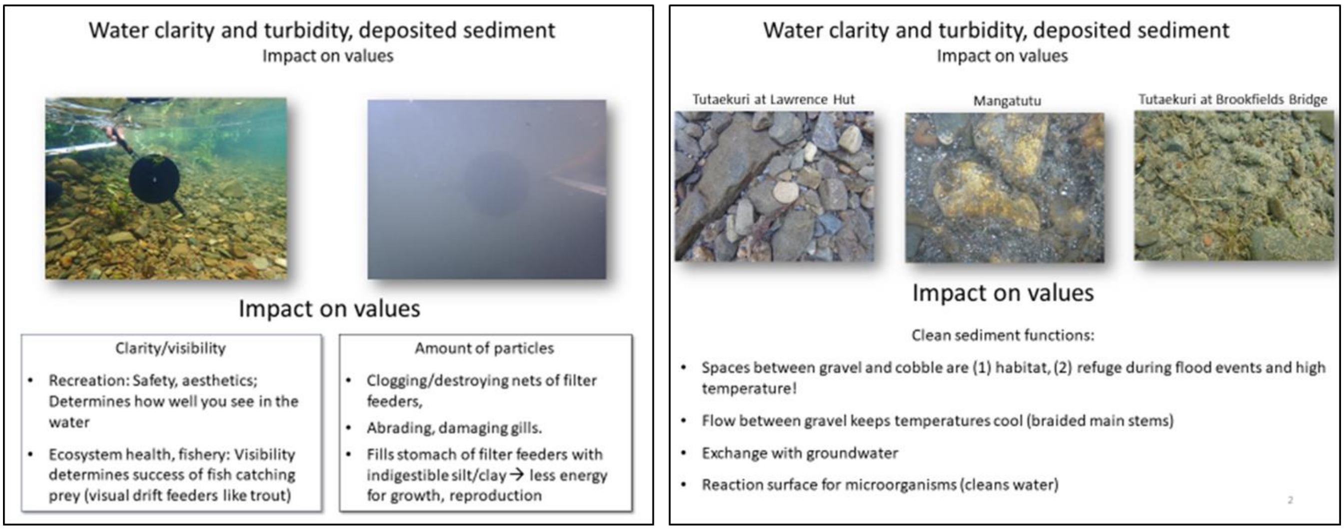
ECONOMIC, TOURISM

- Algal thresholds link to values
- Nutrients link to algal growth, but not directly to values

Nutrient management DIN and DRP (Ngaruroro co-limited)
2 options: against guidelines or relative to current state of algal growth?

Figure 2-1: Example slide on attributes related to algal growth. TANK meeting 21 (28.6.2016).

For instream sediment, the relationship between clarity and turbidity and the difference in the effect of suspended sediment and deposited sediment on values (recreation, trout fishery and ecosystem health) was explained (Fig 2-2).



Water clarity and turbidity, deposited sediment
Impact on values

Impact on values

Clarity/visibility

- Recreation: Safety, aesthetics; Determines how well you see in the water
- Ecosystem health, fishery: Visibility determines success of fish catching prey (visual drift feeders like trout)

Amount of particles

- Clogging/destroying nets of filter feeders,
- Abrading, damaging gills.
- Fills stomach of filter feeders with indigestible silt/clay → less energy for growth, reproduction

Water clarity and turbidity, deposited sediment
Impact on values

Impact on values

Clean sediment functions:

- Spaces between gravel and cobble are (1) habitat, (2) refuge during flood events and high temperature!
- Flow between gravel keeps temperatures cool (braided main stems)
- Exchange with groundwater
- Reaction surface for microorganisms (cleans water)

Figure 2-2: Example slide on sediment attributes. Suspended sediment, deposited sediment and their impact on values. Left slide: discussion on water clarity, right slide: discussion on deposited sediment.

For streams in the Karamū catchment, a lowland, predominantly soft sediment and macrophyte dominated catchment, issues and cause-effect relationships were different to the algal dominated catchments.

Information was given on the ecosystem health of the catchment: The Karamū catchment has the lowest MCI values in Hawke's Bay, and a targeted study was carried out to identify the main stressors affecting ecosystem health in this area. Maximum water temperature, minimum DO concentration and habitat quality were most strongly correlated to changes in macroinvertebrate community composition. The abundance of mayflies and caddisflies - and MCI scores - were lowest at sites with high maximum temperature and low daily oxygen minima. These appeared to be the major factors compromising life-supporting capacity in the study streams (Fig 2-3) (Haidekker, 2016a).

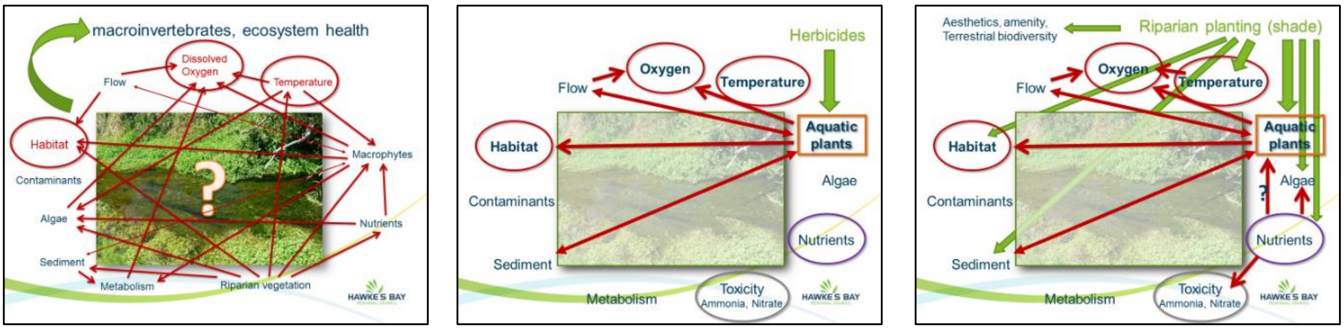
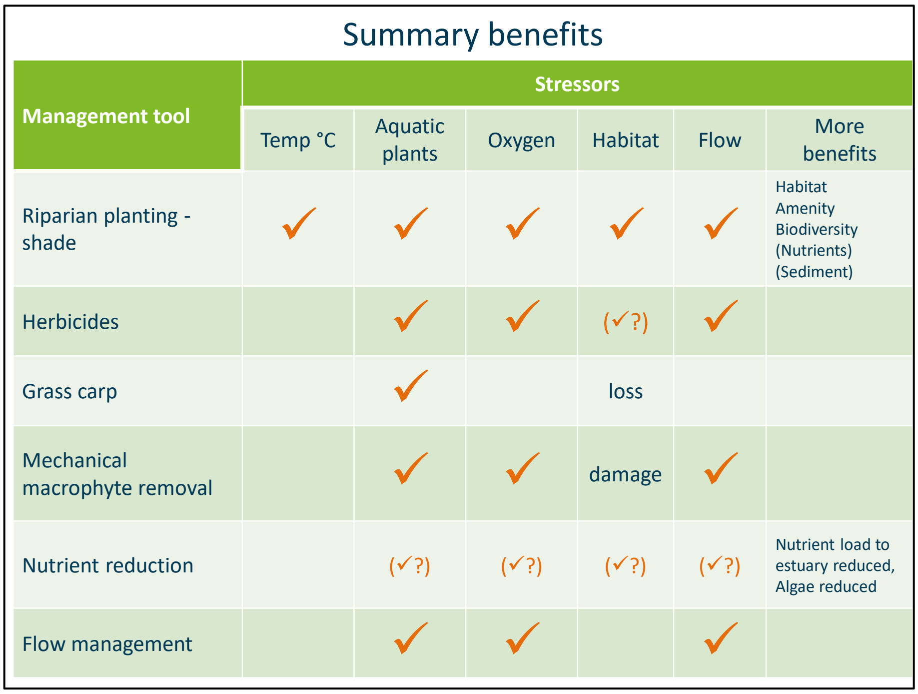


Figure 2-3: Example slides on identifying key stressors and management options. Discussion slides on multiple stressors and interactions to identify key stressors and management options: example macrophyte dominated lowland streams. TANK meeting 25 (13.12.2016).

The relationship between MCI, temperature, oxygen, flow and riparian vegetation was discussed. A workshop provided advice on how to manage the specific set of problems in lowland catchments such as the Karamū and the management options were discussed with the TANK Group (Matheson et al., 2017).

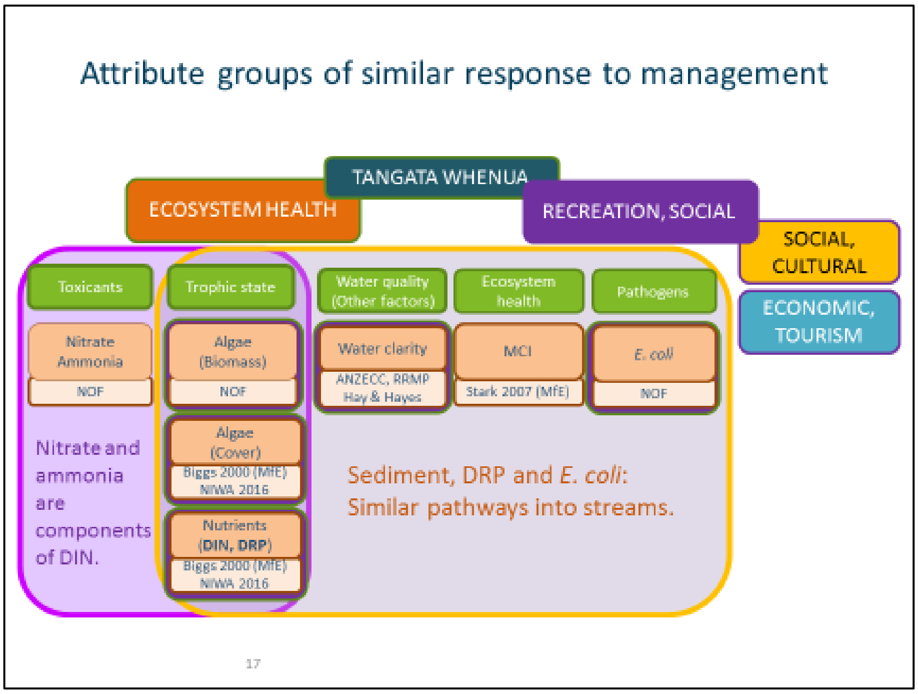


Summary benefits

Management tool	Stressors					
	Temp °C	Aquatic plants	Oxygen	Habitat	Flow	More benefits
Riparian planting - shade	✓	✓	✓	✓	✓	Habitat Amenity Biodiversity (Nutrients) (Sediment)
Herbicides		✓	✓	(✓?)	✓	
Grass carp		✓		loss		
Mechanical macrophyte removal		✓	✓	damage	✓	
Nutrient reduction		(✓?)	(✓?)	(✓?)	(✓?)	Nutrient load to estuary reduced, Algae reduced
Flow management		✓	✓		✓	

Figure 2-4: Example slide on management options and benefits in the Karamū catchment. Meeting 25 (13 December 2016). Stressors discussed in TANK meeting: Temp°C: water temperature; Aquatic plants: macrophytes; Oxygen: instream dissolved oxygen; Habitat: instream and riparian habitat; Flow: Flow conveyance.

Management options were discussed in their relation to groups of attributes that are simultaneously covered. For example sediment management is a key contaminant pathway that also addresses phosphorus and bacteria losses. Depending on management methods, nitrogen (DIN) management can also address nitrate and ammonia toxicity problems (Figure 2-5).



Attribute groups of similar response to management

TANGATA WHENUA

ECOSYSTEM HEALTH

RECREATION, SOCIAL

SOCIAL, CULTURAL

ECONOMIC, TOURISM

Toxicants

Nitrate Ammonia

NOF

Trophic state

Algae (Biomass)

NOF

Algae (Cover)

Biggs 2000 (MfE) NIWA 2016

Nutrients (**DIN, DRP**)

Biggs 2000 (MfE) NIWA 2016

Water quality (Other factors)

Water clarity

ANZECC, RRMP Hay & Hayes

Ecosystem health

MCI

Stark 2007 (MfE)

Pathogens

E. coli

NOF

Nitrate and ammonia are components of DIN.

Sediment, DRP and *E. coli*: Similar pathways into streams.

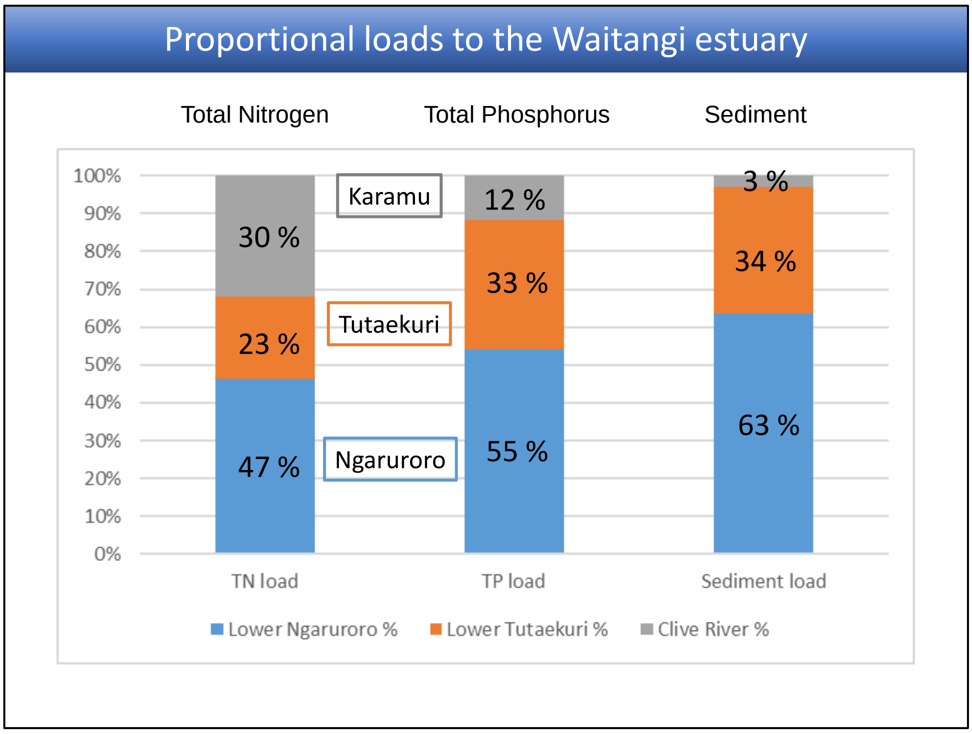
Figure 2-5: Example slide on contaminant groups with similar response to management. TANK meeting 22 (9.8.2018).

2.2.2 Managing attributes in relation to local or downstream (receiving) environments

The origin of issues affecting catchment values varies, and the location of areas in a catchment affected by managing attributes also varies. During discussions on different freshwater management areas, the TANK Group was informed about spatial aspects of managing attributes. For example:

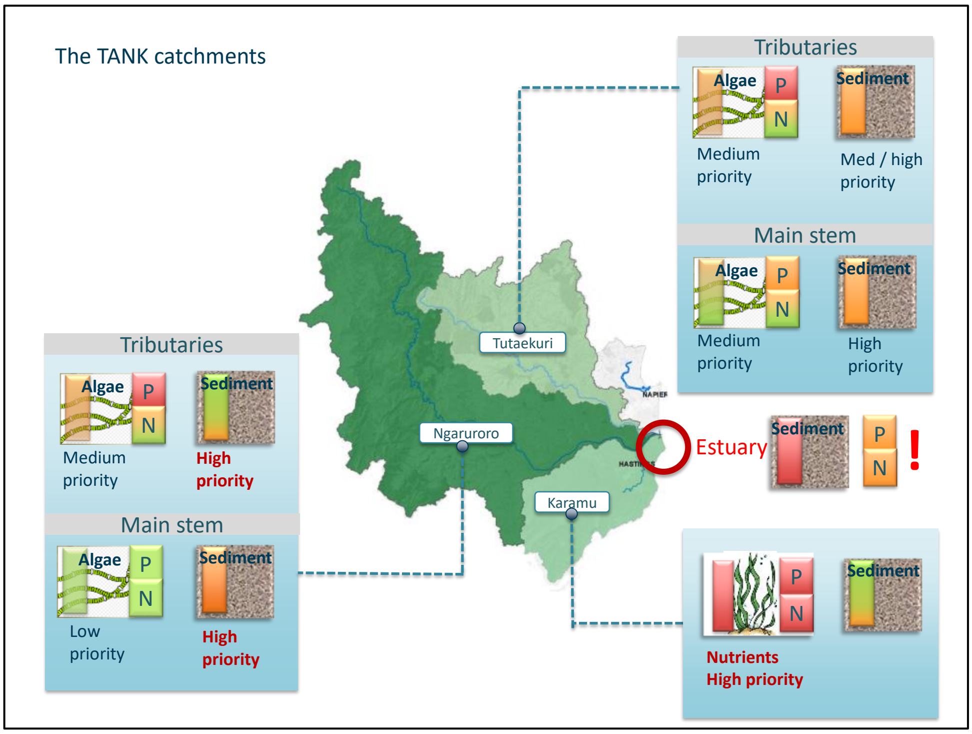
- Riparian management has a local effect by shading macrophyte growth and providing habitat within the same reach, but has a downstream effect on temperature
- Sediment input from stream banks eroded by stock access has a local effect as sediment deposited under dry conditions, while during rainfall events suspended sediment affects clarity, and is deposited in estuaries
- For managing algae, instream nutrient concentrations are of relevance, whereas for the estuary total loads of sediment and nutrients are important
- While macrophytes are difficult to manage through nutrient reduction, nutrient reduction in the macrophyte dominated Karamū catchment is important in order to reduce the nutrient load to the estuary.

Therefore, management of attributes for different values needs to take spatial scales into account, particularly the most downstream receiving environment – the Waitangi estuary. Two example slides show how the discussion on these relationships were facilitated (Figure 2-6 and Figure 2-7).



Proportional loads to the Waitangi estuary

Figure 2-6: **Example slide for nutrient and sediment loads to the Waitangi estuary.**



The TANK catchments

Figure 2-7: **Example slide for nutrient and sediment management to protect values in the Waitangi estuary.**

2.2.3 Setting management priorities

The next step was to understand the water quality objectives (attribute-values relationships) in context with the current state in the TANK catchment: to identify issues i.e. where at a given objective, improvements would need to be made. Relationships between attributes and values were discussed.

The TANK Group discussed where in the catchments the water quality was good and therefore protecting the values that were identified for the TANK catchments. They decided that for any specific water body where the attribute state is found to be higher than the objective, the higher state is to be maintained, which is at the measured state. The state is as measured according to the method specified for each attribute. It does not allow for a decline to a lower state within any band specified in the NPS-FM: 2014 (as amended 2017).

Issues were identified where guidelines (attributes) weren't met at SOE or 'gap'-sites, and by looking at how far sites were away from a desired state. This is the case when current state is below bottom line for compulsory NOF attributes, or when objectives were set higher than the bottom line and current state does not meet this objective, or where for other attributes the current state is far from the desired state. This enabled discussion on setting management priorities. To assist this discussion, slides were prepared to visualise how far a site is from a desired state (for example: Figure 2-8). A table for future reference was prepared with summary statistics of SOE results, which were compared with objectives set by the TANK Group. Data for sites where guidelines were not achieved were marked in red. The full table is in Appendix A.

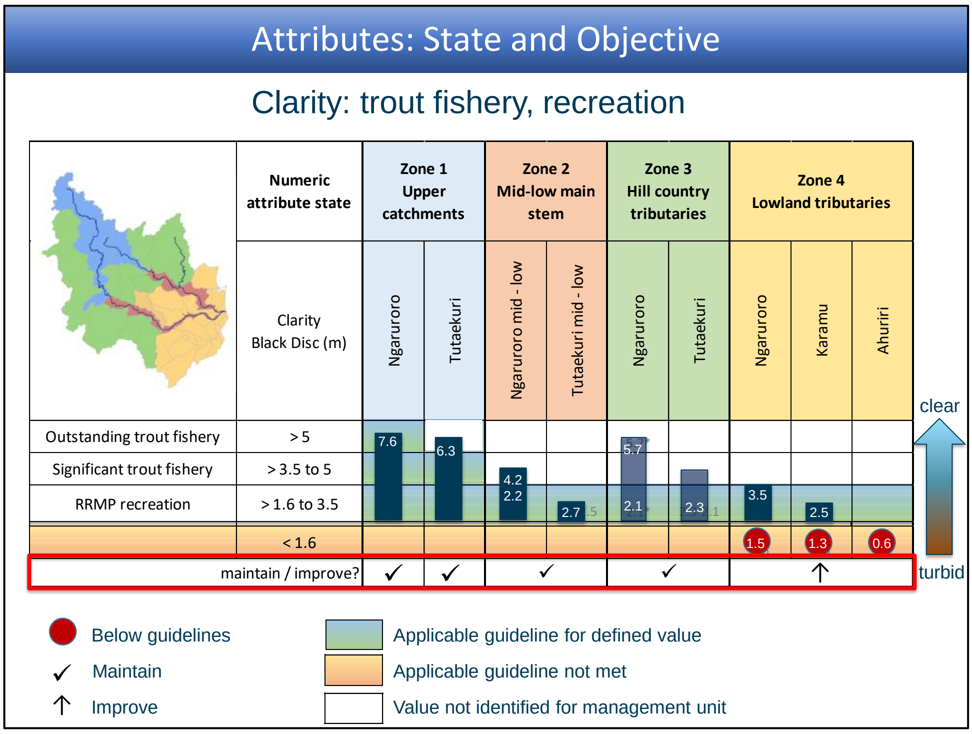


Figure 2-8: Example slide to identify issues in the TANK catchments. Visualising if guidelines are met or how far current state is from desired state (objective) in relation to a value. Blue bars: current state (5-year median from SOE data (Haidekker et al., 2016): higher bars indicate better state (in this case clarity [m]), corresponding to value state in the left column. Red dots: current state below NOF bottom line or lowest/ least stringent guideline. More than one value in bar or column indicate there are several monitoring sites in an area and minimum and maximum values are shown in the bar or dot.

Identification of issues in the **Tūtaekurī and Ngaruroro catchments** (tributaries and/or mid to lower main stem):

No or minimal issues:

- Nitrate toxicity
- Ammonia toxicity
- *E. coli* concentration

Identified issues:

- Nutrient concentrations, algal growth
- Suspended sediment, clarity, turbidity (deposited sediment did not have enough consistent data to report at this time)

Karamū/ Clive catchment:

No or minimal issues:

- Ammonia and nitrate toxicity

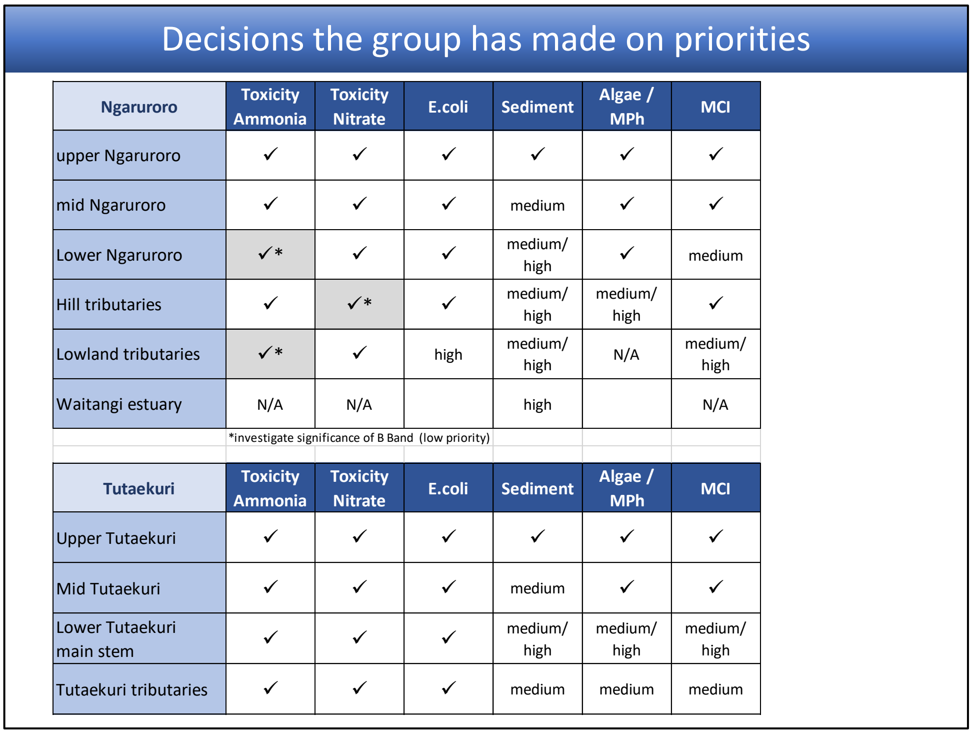
Identified issues:

- High nutrient concentrations
- Nuisance macrophyte growth
- Low dissolved oxygen concentrations, at times anoxia
- High stream temperatures
- Low to very low MCI indicating impaired life supporting capacity

Waitangi Estuary:

Identified issues:

- Nutrients,
- Macroalgal growth
- Anoxia



Decisions the group has made on priorities

Ngaruroro	Toxicity Ammonia	Toxicity Nitrate	E.coli	Sediment	Algae / MPh	MCI
upper Ngaruroro	✓	✓	✓	✓	✓	✓
mid Ngaruroro	✓	✓	✓	medium	✓	✓
Lower Ngaruroro	✓*	✓	✓	medium/ high	✓	medium
Hill tributaries	✓	✓*	✓	medium/ high	medium/ high	✓
Lowland tributaries	✓*	✓	high	medium/ high	N/A	medium/ high
Waitangi estuary	N/A	N/A		high		N/A

*investigate significance of B Band (low priority)

Tutaekuri	Toxicity Ammonia	Toxicity Nitrate	E.coli	Sediment	Algae / MPh	MCI
Upper Tutaekuri	✓	✓	✓	✓	✓	✓
Mid Tutaekuri	✓	✓	✓	medium	✓	✓
Lower Tutaekuri main stem	✓	✓	✓	medium/ high	medium/ high	medium/ high
Tutaekuri tributaries	✓	✓	✓	medium	medium	medium

Figure 2-9: Example slide on setting management priorities, TANK meeting 32 (7.8.2017). Setting management priorities in relation to instream and estuary values. A tick means current state meets objective, maintain current state, or low priority. Shaded boxes mean data indicative only, needs more data or further investigation. N/A: not applicable; MPh: Macrophytes. Algae / MPh for lowland tributaries: Macrophyte dominated lowland tributaries were discussed in a separate meeting on lowland streams together with macrophyte dominated streams in the Karamū catchment.

The SOE and gap sites have a limited spatial cover in the TANK catchments, but nutrient and sediment loads were modelled for the entire TANK area; (for nutrients (SOURCE model, (Williamson and Diack, 2018)) and sediment (SedNet, (Palmer et al., 2016)). The model output was used to complement the spatially limited SOE data to set priorities in the TANK area. With combined measured and modelled data, priorities could be set on areas where the risk of sediment and nutrient loss is particularly high, or where high concentrations or loads were measured (example slide Figure 2-9).

Schedule 3 (Appendix B) sets out a list of priority catchments for management of sediment, nutrients and DO. Using the SedNet and Source models, priority catchments were assigned in relation to each of the water quality issues: catchments with the highest sediment yields, and the highest TN concentrations and yields respectively. A flow-DO model (Wilding, 2016) identified streams most at risk for low DO.

3 Conclusions

In this collaborative process the TANK Group set freshwater quality objectives:

1. Related to values identified for the TANK catchments
2. Based on information for current water quality and ecology.

The upper Ngaruroro and Tūtaekurī (water quality management area 1), is in a near natural state, and the current state is to be maintained. The water quality in the mainstems of the Tūtaekurī and the Ngaruroro (water quality management area 2) is generally good, but hill country tributaries (water quality management area 3) have issues with high nutrient concentrations and some algal blooms. The receiving environment, the Waitangi estuary is in a declining state and has issues with sediment and macroalgae. The TANK Group decided to reduce sediment and nutrient loads, with the focus on protecting the estuary.

Freshwater quality management areas 4 a–d (macrophyte dominated lowland streams marked as yellow areas in the TANK map in Figure 1-6) have issues with ecosystem health as indicated by particularly low MCI, and needs the most improvement. Nuisance macrophyte growth, low dissolved oxygen, high water temperatures and lack of habitat need to be managed. Riparian planting was identified as the main management tool to achieve better ecosystem health. The TANK Group also agreed on reducing nutrients, and sediment in water quality management area 4 to protect the estuary.

The TANK Group agreed on a set of freshwater quality objectives that are compiled in Schedule 1 of TANK Draft Plan Change 9 (Version 8) at the time of compilation of this document (Appendix B Schedule 1: Freshwater Quality Objectives). Te Mana o te Wai, kaitiakitanga and the needs for the values set out in Schedule 1, particularly mauri and ecosystem health are achieved through collectively managing all of the specified attributes. For any specific water body where the attribute state is found to be higher than that given in Schedule 1, the higher state is to be maintained and maintenance of a state is at the measured state[2].

It was a TANK Group desire to include an additional Schedule 2 (Appendix B Schedule 2: Freshwater Quality Objectives) to satisfy cultural and social needs for a long term and more integrated approach to the way freshwater is managed. It also provides additional direction for the monitoring and research efforts of the Council. This is particularly relevant for the integration of freshwater and estuary ecosystems. Schedule 2 does not have a regulatory function. The quality of the TANK freshwater bodies set out in Schedule 2 will be implemented through future plan changes.

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[2] The state is as measured according to the method specified for each attribute. It does not allow for decline to a lower state within any band specified in the NPS-FM 2014 (as amended 2017);

4 Acknowledgements

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I thank the members of the TANK Group for the discussions and for sharing their visions, widening my view in many ways.

5 Glossary of abbreviations and terms

ANZECC	Australian and New Zealand Environment and Conservation Council
BOD	Biological Oxygen Demand
CRI	Cox-Rutherford-Index
DO	Dissolved Oxygen
FENZ	Freshwater Environments New Zealand 2010
HBRC	Hawke's Bay Regional Council
MfE	Minitry for the Environment
NOF	National Objectives Framework
NPS-FM	National Policy Statement for Freshwater Management 2014
POM	Particulate Organic Matter
RMA	Resource Management Act 1991
RRMP	Regional Resource Management Plan 2006
SOE	State of the Environment
TANK	Tūtaekurī, Ahuriri, Ngaruroro and Karamū catchments

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Appendix A Water quality objectives in comparison with SOE data

(as amended after Meeting 39, 19-Apr-2018). This table combines values, attributes and SOE data. It is a summary of meetings in which attributes were discussed separately, and was meant to support discussion on current state and discussed objectives. This was a working/discussion table. Final objectives in Schedule 1 and 2 may differ from numbers shown here. First column: Green shaded boxes indicate attributes, applicable guidelines. Second column relates to rows: TANK GL: guidelines, thresholds, objectives the TANK Group agreed on (bold numbers). SOE 2013 – state: data from 5-year SOE report (2009-13). SOE 2014-16 – state: updated data; values in black are meeting objectives, values in red are not meeting objectives. For areas with more than 3 monitoring sites min-max values given. Value/Objective: value and level (state, objective) to which the TANK guideline protects the value in a freshwater management area. Reference: See Appendix C.

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
Critical Value[1]		Ngaruroro (Kurip/*Whana*)	Tūtaekurī (Lawrence Hut)	Ngaruroro (Fernhill)	Tūtaekurī (Brookfields Br)	Ngaruroro (Taruarau/ Poporangi/ Maraekakaho)	Tūtaekurī (MangaoneR / Mangatutu)	Ngaruroro (Ohiwia, Waitio, Tut-Waim)	Karamū (7 sites)	Ahuriri (Taipo)
Sediment – clarity (Black disc (metres), median)	TANK GL	**≥5**	**≥5**	**≥1.6**	**≥1.6**	**≥1.6**	**≥1.6**	**>1.6**	**>1.6**	**>1.6**
trout fishery at < median flows	SOE 2013 - state	7.3* / 4.9*	5.9	1.18	1.89	>1.65	1.4 - 1.9	O:3.0/W:3.0/TW: 1.1	1 - 1.25	0.54
ANZECC at all flows	SOE 2014-16 - state	all flows (5.7 / 3.6)	7.6	1.12	2.5	T:3.8/P:1.9/M: 3.3	2.15/1.7	O:3.45/W:5.2/ TW:1.96	1.3 - 2.45	0.3
	Value/ Objective	Trout fishery - outstanding	Trout fishery - outstanding	Recreation	Recreation	Recreation	Recreation	Recreation	Recreation	Recreation
	Reference	Hay *et al.* 2007	Hay *et al.* 2007	ANZECC/RRMP	ANZECC/RRMP	ANZECC/RRMP	ANZECC/RRMP	ANZECC/RRMP	ANZECC/ RRMP	ANZECC/ RRMP

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
Sediment – turbidity (NTU, median; at flows < median)	TANK GL	**≤0.7**	**≤0.7**	**≤4.1**	**≤4.1**	**≤4.1**	**≤4.1**	**≤5.6**	**≤5.6**	**≤5.6**
trout fishery: <med flows ANZECC: all flows	SOE 2013 - state SOE 2014-16 - state Value/ Objective Reference	0.48 / 1.1 0.59/ 1.9 Trout fishery Hay *et al.* 2007	0.6 0.7 Trout fishery Hay *et al.* 2007	5.2 3.7 trigger value (upland) ANZECC	2.2 1.6 trigger value (upland) ANZECC	T:1.4/P:2.1/M: 0.7 T:1.7/P:2.3/M: 0.9 trigger value (upland) ANZECC	2.0/2.8 2.2/3.2 trigger value (upland) ANZECC	O:1.9/W:1.2/TW:5.1 O:1.1/W:0.9/TW:2.8 trigger value (lowland) ANZECC	≤4 <3 trigger value (lowland) ANZECC	5.8 16 trigger value (lowland) ANZECC
Sediment - deposited sediment (% cover on stream bed)		*<20/ <15 (May-Oct)*	*<20/ <15 (May-Oct)*	*<20*	*<20*	*<20*	*<20*	*<20*	*<20*	*<20*
draft guideline only Recommended to report on average / max	(PC6 : <10) data to come - Timeframe ?									

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
Guideline still in development, changes to protocols. Not enough certainty in data to report.	Value/ Objective Reference	Ecosystem health/ trout spawning Clapcott et al. 2011	Ecosystem health/ trout spawning Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011	Ecosystem health, biodiversity, amenity, recreation Clapcott et al. 2011
Algae – biomass[5] (bloom magnitude (mg/chl-a/m2) and frequency (1 per avge year= 8% of samples=92nd %ile)	TANK GL			>50 - <120 max 1 p.a.	>50 - <120 max 1 p.a.			n/a	n/a	n/a
	SOE Nov2012-14*/16	*30* *A*	*14* *A*	64 (88 d/s HBD) B	104 (u/s Mangaone) B		*61* (small gravel)* *B*			
		only 2 sites retained for national reporting (Tūtaekurī Puketapu, Ngaruroro Fernhill), algal state assessed by % cover at SOE sites								
Ecosystem Health	Value/ Objective	Ecosystem health	Ecosystem health	B - occasional blooms low nutrient enrichment	B - occasional blooms low nutrient enrichment					

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
	Reference	NOF	NOF	NOF	NOF					
Algae – cover (%PeriWCC) (ann max or multiple years (>3) monthly obs 95th %ile, Hazen method	TANK GL	**≤20**	**≤20**	**≤40**	**≤40**	**≤40**	**≤40**	n/a	n/a	n/a
Ecosystem health	*SOE 2013 - state*	n/d	n/d	n/d	n/d	n/d	n/d	n/a	n/a	n/a
	SOE 2013-16 - state	nd/27.3	11.7	42.6	36.4	(T:35)/P:43/M: 89	1.7 / 14 (small gravel)			
	Value/ Objective	Ecological condition excellent	Ecological condition excellent	Ecological condition good	Ecological condition good	Ecological condition good	Ecological condition good			
	Reference	Matheson *et al.* 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016			
Algae – cover (%PeriWCC) (ann max or multiple years (>3) monthly obs 95th %ile, Hazen method	**TANK GL**	**≤30**	**≤30**	**≤30**	**≤30**	**≤30**	**≤30**	n/a	n/a	n/a
Recreation	*SOE 2013 - state*	n/d	n/d	n/d	n/d	n/d	n/d			

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
	SOE 2013-16 - state	nd/27.3	11.7	42.6	36.4	(T:35*)/P:43/ M:89	1.7 / 14 (small gravel)			
	Value/ Objective	Aesthetics/recreation	Aesthetics/recreation	Aesthetics/recreation	Aesthetics/recreation	Aesthetics/recreation	Aesthetics/recreation			
	Reference	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016			
Phormidium (%cover) (MfE alert mode) max	**TANK**	<20	<20	<20	<20	<20	<20	<20	<20	<20
	WCO	<20								
assessments started end 2012	SOE 2012-13 - state	? / 3.4	0.5	0.1	12.3	T:1/P:0/M:0	1.5/81	Waitio: 11.8	0-20 (Poukawa)	
	SOE 2014-16 state	?/7.1	1.1	0	18	T:4.7/P:90/M:2.6	0.3/ 54	Waitio: 43.7	0	n/a
Macrophyte – ann max volume (%CAV) or multiple years (>3) monthly obs 95th %ile Hazen	**TANK GL**	n/a	n/a	n/a	n/a	n/a	n/a	**≤ 50**	**≤ 50**	**≤ 50**
Ecosystem Health	SOE 2013 - state							n/d	n/d	n/d

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
	SOE 2013-17 - state					M: 74		O:69/W:76/TW:max46	77-92 56 (Herehere)	99.4
	Value/ Objective							Ecological condition/flow conveyance	Ecological condition/flow conveyance	Ecological condition/flow conveyance
	Reference							Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016
MCI (average)	**TANK GL**	**≥ 120**	**≥ 120**	**≥ 100**	**≥ 100**	**≥ 100**	**≥ 100**	**≥ 90***	**≥ 90***	**≥ 90***
Ecosystem Health	SOE 2013 - state	130/118	127	95	86	T:121/P:109/M:107	103/118	82 - 99	61 - 82	68
*** sb MCI**	SOE 2014-16 - state	/119	131	99	92	T:125/P:115/M:89	100/118	82 - 98	63 - 72	64
	Value/ Objective	Excellent	Excellent	Good	Good	Good	Good	Fair	Fair	Fair
	Reference	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007	Stark & Maxted 2007
DIN (mg/l, median, all flows)	**TANK GL**	**< 0.05**	**< 0.05**	**< 0.15**	**< 0.15**	**< 0.3**	**< 0.3**	**< 0.444**	**< 0.444**	**< 0.444**

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
Algal growth/ estuary ecosystems risk of algae to reach 30% cover (recreation)	SOE 2013 - state	0.009/0.044	0.027	0.134	0.155	T:0.026/P:0.538/M:0.419	0.335/0.334	O:0.499/W:0.247/ TW:0.253	0.3 - 1.7	0.471
	SOE 2014-16 - state	0.02	0.015	0.08	0.083	T:0.017/P:0.466/M:0.22	0.305/0.405	O:0.34/W:0.206/ TW:0.24	0.12 - 0.93	0.221
	Value/ Objective	very low risk	very low risk	low risk	low risk	moderate risk	moderate risk	trigger value	trigger value	trigger value
	Reference	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	ANZECC	ANZECC	ANZECC
DRP (mg/l, median, all flows)	**TANK GL**	**<0.003**	**<0.003**	**<0.015**	**<0.015**	**<0.015**	**<0.015**	**<0.015** (0.026?)	**<0.015** (0.026?)	**<0.015** (0.026?)
Algal growth/ estuary ecosystems risk of algae to reach 30% cover (recreation)	SOE 2013 - state	0.002/0.002	0.004	0.007	0.016	T:0.002/P:0.025/M:0.025	0.019/0.018	O:0.111/W:0.025/ TW:0.031	0.034 - 0.18	0.27
	SOE 2014-16 - state	0.002	0.004	0.007	0.018	T:0.002/P:0.028/M:0.022	0.026/0.02	O:0.103/W:0.022/ TW:0.03	0.027 - 0.14	0.27
	2017	0.002	0.004	0.009	0.025	P:0.011/M:0.026	0.03/0.02	O:0.131/W:0.026/ TW:0.036	0.024 - 0.21	0.26
	Value/ Objective	very low risk	very low risk	moderate risk	moderate risk	moderate risk	moderate risk			

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
	Reference	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	Matheson et al. 2016	RRMP (MfE 20d Pph accrual)	RRMP (MfE 20d Pph accrual)	RRMP (MfE 20d Pph accrual)
Nitrate (mg NO_3-N/l, all flows) **annual** median, **annual** 95th%ile	**TANK GL**	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5	median ≤ 1 95th%ile ≤ 1.5
toxicity	SOE 2012-16 - state median	<1	<1	<1	<1	M:<1 (annual)	<1	no exceedances	Awanui, Karewarewa, Clive (3/5), Here (1/5), Awanui (5/5), Karew(5/5), Pou (2/5) Rau (1/3)	<1
normally reported on annual basis, in this table only exceedance highlighted	SOE 2012-16 - state 95th%ile	<1	<1	<1	<1	M:>1.5	Mangaone 1 exc in 5 years	no exceedances		(1/5)
if max <1 mg/L, then below all GL	*SOE 2012-16 - state max*	*<1*	*<1*	*<1*	*<1*	*T:<1/P<1/M:2.7*	*>1 / <1*	*O:=1/W:<1/TW:2.3*		
	Value/ Objective	A - unlikely to be effect on any species, high	A - unlikely to be effect on any species, high	A - unlikely to be effect on any species, high	A - unlikely to be effect on any species, high	A - unlikely to be effect on any species, high	A - unlikely to be effect on any species, high	A - unlikely to be effect on any species, high	A - unlikely to be effect on any	A - unlikely to be effect on any

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
		conservation value	conservation value	conservation value	conservation value	conservation value	conservation value	conservation value	species, high conservation value	species, high conservation value
	Reference	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM
Ammonia (mg NH_4-N/l, all flows) **annual** median, **annual** max unionised ammonia based on pH8 at 20°C	**TANK GL**	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05	median ≤ 0.03 max ≤ 0.05
toxicity	SOE 2012-16 - state median									
current state data pH and temp adjusted	SOE 2012-16 - state max	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	5-year max at all SOE sites <0.03	max over 5 years 0.034
	Value/ Objective	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species	A-99% spec protection, no effect on any species

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
	Reference	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM	NPS-FM
***E. coli*[6]** (cfu/100 ml)	**TANK GL**	<5% over 260/100ml[7] median < 130/100ml	<5% over 260/100ml[7] median < 130/100ml	<5% over 540/100ml[7] median < 130/100ml	<5% over 540/100ml[7] median < 130/100ml	<5% over 540/100ml[7] median < 130/100ml	<5% over 540/100ml[7] median < 130/100ml	<5% over 1000/100ml[7] median < 130/100ml	<5% over 1000/100ml[7] median < 130/100 ml	<5% over 1000/100ml[7] median < 130/100 ml
Mauri/Recreation/human health	SOE 2013 - state 95%ile	65/120	35	340	156	T:233/P:245/M:823	1426/294	O:1756/W:1500/TW:2615	Poukawa:634; 1585-21535	2360
	SOE 2013 - state median	3/3	11	26	16	T:12/P:58/M:61	38/42	O:180/W:35/TW:87	Poukawa:90 190-540	330
	SOE 2014-16 - state 95%ile	56/283	70	410	260	T:94/P:109/M:410	803/1434	O:321/W:115/TW:548	Poukawa:388; 1900-16225 (Clive)	6400
	SOE 2014-16 - state median	3/3	13	30	12	T:16/P:35/M:60	35/36	O:72/W:23/TW:64	190-600	1450
	Value/ Objective	more stringent than (A) rarely past 'excellent'	more stringent than (A) rarely past 'excellent'	(A) rarely past 'excellent'	(A) rarely past 'excellent'	(A) rarely past 'excellent'	(A) rarely past 'excellent'	(B) rarely past 'good'	(B) rarely past 'good'	(B) rarely past 'good'

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
Most critical values discussed here, all MfE NOF bands applied in Plan	Reference	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package	MfE 2017 Clean Water Package
Dissolved oxygen (mg/L or %)proposed	TANK GL	≥8 (7-d mean min) / ≥7.5 (1-d min) / ≥80% saturation	≥8 (7-d mean min) / ≥7.5 (1-d min) / ≥80% saturation	≥8 (7-d mean min) / ≥7.5 (1-d min) / ≥80% saturation	≥8 (7-d mean min) / ≥7.5 (1-d min) / ≥80% saturation	≥8 (7-d mean min) / ≥7.5 (1-d min) / ≥80% saturation	≥8 (7-d mean min) / ≥7.5 (1-d min) / ≥80% saturation	≥5 (7-d mean min) / ≥4 (1-d min)	≥5 (7-d mean min) / ≥4 (1-d min)	≥5 (7-d mean min) / ≥4 (1-d min)
Ecosystem health	7-d mean min	no data	no data	no data	no data	no data	no data	W: 5.3	anoxia--5.5	1.2
7-day mean minimum (mean of 7 consecutive daily min values)	1-d min	no data	no data	no data	no data	no data	no data	W: 5	anoxia--5.0	0.7
1-day minimum (lowest daily min across summer period)	No SOE data. Targeted study									
(Summer Period: 1 November to 30th April)	Value/ Objective	Band A No stress caused by low dissolved oxygen on any aquatic	Band A No stress caused by low dissolved oxygen on any aquatic	Band A No stress caused by low dissolved oxygen on any aquatic	Band A No stress caused by low dissolved oxygen on any aquatic	Band A No stress caused by low dissolved oxygen on any aquatic organisms that	Band A No stress caused by low dissolved oxygen on any aquatic	**Band C** (long term Band B in Schdule 2 (≥7 / ≥5)	**Band C** (long term Band B in Schdule	**Band C** (long term Band B in Schedul

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
continuous data only for risk sites (MPh dominated, low gradient)	Reference	organisms that are present at matched reference (near-pristine) sites. NPS-FM	organisms that are present at matched reference (near-pristine) sites. NPS-FM	organisms that are present at matched reference (near-pristine) sites. NPS-FM	organisms that are present at matched reference (near-pristine) sites. NPS-FM	are present at matched reference (near-pristine) sites. NPS-FM	organisms that are present at matched reference (near-pristine) sites. NPS-FM	NPS-FM	2 (≥7 / ≥5) NPS-FM	e 2 (≥7 / ≥5) NPS-FM
Temperature (°C) 5-day CRI	TANK	≤22 (relative reference A)	≤22 (relative reference A)	≤23 (relative reference B)	≤23 (relative reference B)	≤23 (rel ref B) (≤21)^{Tab2}	≤23 (rel ref B) (≤21)^{Tab2}	≤23 (rel ref B) (≤21)^{Tab2}	≤23 (rel ref B) (≤21)^{Tab2}	≤23 (rel ref B) (≤21)^{Tab2}
Proposed NOF Eastern dry region	proposed NOF region	≤ 19 (A)	≤ 19 (A)	≤ 21 (B)	≤ 21 (B)	≤ 21 (B)	≤ 21 (B)	≤ 21 (B)	≤ 21 (B)	≤ 21 (B)
Proposed NOF reference method	proposed NOF reference method	≤ 22 (A)	≤ 22 (A)	≤ 23 (B)	≤ 23 (B)	≤ 23 (B)	≤ 23 (B)	≤ 23 (B)	≤ 23 (B)	≤ 23 (B)
Ecosystem health Cox Rutherford Index	CRI	20.7/21.6	20.1	24.5	22.6 (Puketapu) 24.6 (Dartmoor)	T:20.7/P:23.1	24.5/22.3	TW20.3	19.7 - 24	23

		Area 1 Upper catchments		Area 2 Mid-low main-stem		Area 3 Algae dominated hill country tributaries		Area 4 Macrophyte dominated tributaries (Heretaunga Plains)		
mean CRI over 5 hottest summer days CRI= average daily mean and max temp	Value/ Objective	(relative reference A)	(relative reference A)	(relative reference A)	(relative reference A)	≤21 Table 2	≤21 Table 2	≤21 Table 2	≤21 Table 2	≤21 Table 2
	Reference	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds	Davies-Colley et al proposed NOF thresholds

Appendix B Proposed PC9 Freshwater Quality Objectives as of December 2018

SCHEDULE 1: FRESHWATER QUALITY OBJECTIVES

Water quality attribute	Surface WQ areas[1]	Water Quality Objective or /Target[2]	Application	Critical Value [3]	Also relevant for
Water clarity (m)	Upper Ngaruroro and Upper Tūtaekurī Rivers	≥ 5 m	Median, <median flows	Trout fishery - outstanding	Recreation, ecosystem health, mauri, natural character, Uu, amenity natural character, indigenous biodiversity and mahinga kai, taonga and tohu species and habitat, abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use
	Lower Ngaruroro and Lower Tūtaekurī Rivers	≥ 3.75 m		Trout fishery - significant	
	Ngaruroro and Tūtaekurī Tributaries	≥ 3.75 m			
	Lowland tributaries	≥ 1.6 m	Median, all flows	Recreation / aesthetics	
Turbidity (NTU)	Upper Ngaruroro and Upper Tūtaekurī Rivers	≤ 0.7	Median, at < median flows	trout fishery	Recreation, ecosystem health, UU, ecosystem health, kaitiakitanga, waimaori, natural character, mauri, domestic and farm water supply

	Lower Ngaruroro and Lower Tūtaekurī Rivers	≤ 4.1	Median, all flows	statistical GL	UU, ecosystem health, kaitiakitanga, waimaori, natural character, mauri, abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use.
	Ngaruroro and Tūtaekurī Tributaries	≤ 4.1			
	Lowland tributaries	≤ 5.6			
Deposited sediment (%)	Upper Ngaruroro and Upper Tūtaekurī Rivers	< 20% / < 15% (May-Oct)	Run habitats, maximum	Ecosystem health Biodiversity (MCI), salmonid spawning	Uu, waimaori, natural character, mauri, ecosystem health, kaitiakitanga- ahu whenua mahinga kai, he aha haere, taonga/tohu species habitat and spawning, cultural practices, wetlands and lakes, maori land, marae/hapū, indigenous biodiversity
	Lower Ngaruroro and Lower Tūtaekurī Rivers	< 20 %		Ecosystem health (Biodiversity (MCI))	
	Ngaruroro and Tūtaekurī Tributaries	< 20 %			
	Lowland tributaries	< 20 %			
Periphyton biomass (mg/m^2)[4]	Lower Ngaruroro and Lower	>50 - <120 mg/m^2 max 1 p.a.	max 8% exceedance over 3 years monthly observations	Ecosystem health (NOF)	Uu, waimaori, natural character, mauri, ecosystem health, kaitiakitanga, he aha haere, taonga/tohu species habitat and spawning, mahinga kai,

	Tūtaekurī Rivers				nohoanga, cultural practices, tauranga waka, maori land, marae/hapū, indigenous biodiversity
Periphyton cover (annual max, %PeriWCC)	Upper Ngaruroro and Upper Tūtaekurī Rivers	≤ 20 %	Monthly observations, all year.	Ecosystem health	Uu, waimaori, natural character, mauri, ecosystem health, kaitiakitanga, he aha haere, taonga/tohu species habitat and spawning, mahinga kai, nohoanga, cultural practices, tauranga waka, maori land, marae/hapu, indigenous biodiversity abstractive uses including stock drinking
	Lower Ngaruroro and Lower Tūtaekurī Rivers	≤ 40 %			
	Ngaruroro and Tūtaekurī Tributaries	≤ 40 %			
Periphyton cover (seasonal max, %PeriWCC)	Upper Ngaruroro and Upper Tūtaekurī Rivers	≤ 30 %	Monthly observations, , all year (for Uu)	Recreation	Uu, waimaori, natural character, mauri, ecosystem health, kaitiakitanga, he aha haere, taonga/tohu species habitat and spawning, mahinga kai, nohoanga, cultural practices, tauranga waka, maori land, marae/hapū, abstractive uses including stock drinking
	Lower Ngaruroro and Lower Tūtaekurī Rivers	≤ 30 %			
	Ngaruroro and Tūtaekurī Tributaries	≤ 30 %			

Cyanobacteria (benthic cover %)[5]	All Management Areas	< 20 %	Monthly observations, all year.	Recreation	Uu, waimaori, natural character, mauri, ecosystem health, kaitiakitanga, he aha haere, taonga/tohu species habitat and spawning, mahinga kai, nohoanga, cultural practices, tauranga waka, maori land, marae/hapū, abstractive uses including stock drinking
Macrophytes (max %CAV)	Lowland tributaries	≤ 50 %	Monthly observations, all year.	Ecosystem health	Uu, waimaori, natural character, mauri, ecosystem health, kaitiakitanga, he aha haere, taonga/tohu species, mahinga kai, nohoanga, cultural practices, tauranga waka, Indigenous biodiversity, abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use
	Upper Ngaruroro and Upper Tūtaekurī Rivers	≥ 120	average, flow < median	Ecosystem health	Waimaori, natural character, mauri, ecosystem health, kaitiakitanga, whakapapa, taonga/tohu species habitat and spawning, Indigenous biodiversity, trout
	Lower Ngaruroro and Lower Tūtaekurī Rivers	≥ 100			
	Ngaruroro and Tūtaekurī Tributaries	≥ 100			
	Lowland Tributaries (sb-MCI)	≥ 90			Waimaori, natural character, mauri, ecosystem health, kaitiakitanga, whakapapa, indigenous

					biodiversity and taonga/tohu species habitat and spawning
DIN (mg/L)	Upper Ngaruroro and Upper Tūtaekurī Rivers	< 0.05 mg/L	Median, all flows	Algal growth	Estuary ecosystem health, recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, ecosystem health, abstractive uses, drinking water
	Lower Ngaruroro and Lower Tūtaekurī Rivers	< 0.15 mg/L			Estuary ecosystem health, recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, ecosystem health, abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use
	Ngaruroro and Tūtaekurī Tributaries	< 0.3 mg/L			Estuary ecosystem health, recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, abstractive uses, drinking water
	Lowland tributaries	< 0.444 mg/L		Estuary ecosystem health	Recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, ecosystem health, abstractive uses including for domestic, farm and community water supply, primary production, industrial and commercial use
DRP (mg/L)	Upper Ngaruroro and Upper Tūtaekurī Rivers	< 0.003 mg/L	Median, all flows	Algal growth	Estuary ecosystem health, recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, abstractive uses
	Lower Ngaruroro and Lower	< 0.015 mg/L		Algal growth	Estuary ecosystem health, recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, aquifer recharge, abstractive uses

	Tūtaekurī Rivers				
	Ngaruroro and Tūtaekurī Tributaries	< 0.015 mg/L		Algal growth	Estuary ecosystem health, recreation, uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, abstractive uses
	Lowland tributaries	< 0.015 mg/L		Estuary ecosystem health	Uu, waimaori, mauri, aquifer recharge, mahinga kai, taonga/tohu species, natural character, ecosystem health, abstractive uses
Nitrate (mg NO3-N/L)	Upper Ngaruroro and Upper Tūtaekurī Rivers	median ≤ 1 / 95th%ile ≤ 1.5	annual median, annual 95th%ile (Hazen method), all flows	Toxicity (NOF)	Waimaori, mauri, aquifer recharge, indigenous taonga/tohu species habitat and spawning, ahu moana Abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use
	Lower Ngaruroro and Lower Tūtaekurī Rivers				
	Ngaruroro and Tūtaekurī Tributaries				
	Lowland Streams	median ≤ 2.4 / 95th%ile ≤ 3.5			
Ammonia (mg NH4-N/L)	Upper Ngaruroro and Upper Tūtaekurī Rivers	median ≤ 0.03 / max ≤ 0.05	Annual median, annual max unionised ammonia based	Toxicity (NOF)	Waimaori, mauri, aquifer recharge, indigenous taonga/tohu species habitat and spawning, ahu moana

	Lower Ngaruroro and Lower Tūtaekurī Rivers		on pH8 at 20^0, all flows		Abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use
	Ngaruroro and Tūtaekurī Tributaries				
	Lowland tributaries				
E. coli (cfu/100 ml)	Upper Ngaruroro and Upper Tūtaekurī Rivers	<5% over 260/100ml median < 130/100ml	All year, all flows	recreation / human health, Uu	Waimaori, , mauri, kaitiakitanga, he aha haere, aquifer recharge, ahu moana, ahuwhenua mahinga kai, nohoanga, cultural practices, tauranga waka, , maori land, marae/hapū connections, abstractive uses including for domestic, farm and community water supply, primary production and food production, industrial and commercial use
	Lower Ngaruroro and Lower Tūtaekurī Rivers	<5% over 540/100ml <20% over 260/100ml median < 130/100ml			
	Ngaruroro and Tūtaekurī Tributaries	<5% over 540/100ml <20% over 260/100ml median < 130/100ml			
	Lowland tributaries	<5% over 1000/100ml median < 130/100ml <30% over 260/100ml <10% over 540/100ml <			

		l			
Dissolved oxygen (mg/L or %) from continuous data	Upper Ngaruroro and Upper Tūtaekurī Rivers	≥8 (7-d mean min) / ≥7.5 (1-d min) / (≥80% saturation)	7-day mean min; 1-day min (Nov- April)	Ecosystem health	Waimaori, natural character, mauri, kaitiakitanga, whakapapa, indigenous taonga/tohu species, indigenous biodiversity, trout
	Lower Ngaruroro and Lower Tūtaekurī Rivers				
	Ngaruroro and Tūtaekurī Tributaries				
	Lowland tributaries	≥5 (7-d mean min) / ≥4 (1-d min)			Waimaori, natural character, mauri, kaitiakitanga, whakapapa, indigenous taonga/tohu species, indigenous biodiversity
Temperature (°C) 5-day CRI from continuous data	Upper Ngaruroro and Upper Tūtaekurī Rivers	≤ 22°C	Cox-Rutherford-Index from continuous measurements, hottest 5 consecutive days, all flows	Ecosystem health	Waimaori, natural character, mauri, kaitiakitanga, whakapapa, taonga/tohu species, ahumoana, ahuwhenua mahinga kai indigenous biodiversity, trout
	Lower Ngaruroro and Lower Tūtaekurī Rivers	≤ 23°C			

	Ngaruroro and Tūtaekurī Tributaries	≤ 23°C			
	Lowland tributaries	≤ 23°C[9]			Waimaori, natural character, mauri, kaitiakitanga, whakapapa, taonga/tohu species, ahumoana, ahuwhenua mahinga kai Indigenous biodiversity
pH	Upper Ngarororo and Tūtaekurī	6.5 – 8.	At all times, 95th %ile	Ecosystem health	
	All areas (not upper Ngaruroro and Tūtaekurī)	6.5- 8.5		Ecosystem health	
BOD (ScBOD$_5$)[10]	All areas	<2 mg/l	Flow <median	Ecosystem health	
Heavy metals and metalloids, pesticides and organic contaminants, radioactive contaminants[10]	Upper Ngaruroro and Upper Tūtaekurī Rivers	99% species protection	At all times	Ecosystem Health	
	All areas (not upper Ngaruroro and Tūtaekurī)	95% species protection	At all times	Ecosystem Health	

Placeholder for mātauranga Māori attributes that are yet to be developed					

*the areas that these water quality objectives refer to are on the attached planning maps

Note 1; Surface water quality management areas for rivers. The management areas are shown on the Planning Maps Details for wetland and lake water quality targets and limits still to come.

Note 2; Where the numeric number is currently being met it is the freshwater objective, and if it is not currently being met then it is a target.

Note 3; The critical value is the value most sensitive to the attribute state (has the highest water quality demand for that attribute). If the needs of the critical value are met, the needs of other values are also met.

Note 4; The council collects information about the periphyton biomass at a limited number of sites. It also has extensive data on periphyton cover, including cyanobacteria at all SOE sites

Note 5; MfE Alert-level framework: New Zealand guidelines for cyanobacteria in recreational fresh waters: Interim guidelines (2009)

Note 6; Maximum 95th percentile concentration of nitrate-nitrogen (mg N-NO3 /l) shall be calculated as the 95th percentile of monitoring results obtained over a period of 5 consecutive years

Note 7; Some aesthetic determinants including iron, manganese and hardness are affected by geological conditions and will affect natural water quality

Note 8; the attributes are as measured in groundwater at 10m below ground level

Note 9; subject to external review

Note 10; Attribute state established to guide assessment of applications for contaminant discharges

SCHEDULE 2: FRESHWATER QUALITY OBJECTIVES

Schedule 2 does not have a regulatory function. It is not a statutory requirement and is an optional provision. However it is included because it satisfies cultural and social needs for a long term and more integrated approach to the way freshwater is managed. It also provides additional direction for the monitoring and research efforts of the Council. This is particularly relevant for the integration of freshwater and estuary ecosystems

Water quality attribute	Zone	Limit / Objective	Value	Protection level	Application
MCI (index)	Upper Ngaruroro and Upper Tūtaekurī Rivers	≥ 120	Ecosystem health	Ecological condition excellent (for hill country streams and rivers)	average, flow < median
	Lower Ngaruroro and Lower Tūtaekurī Rivers, Ngaruroro and Tūtaekurī Tributaries	≥ 100		Ecological condition good	
	Lowland tributaries	≥ 100		Ecological condition excellent (for lowland streams, Class A)	
Dissolved oxygen (mg/L or %) from continuous data	Upper Ngaruroro and Upper Tūtaekurī Rivers	≥8 (7-d mean min) / ≥7.5 (1-d min) / (≥80% saturation)	Ecosystem health	Band A No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.	Continuous DO measurements
	Lower Ngaruroro and Lower Tūtaekurī Rivers				
	Ngaruroro and Tūtaekurī Tributaries				
	Lowland tributaries	≥7 (7-d mean min) / ≥5 (1-d min)		Band B occasional short periods of minor stress on sensitive organisms.	
	reference	≤ 21°C		Current state reference condition	

Temperature (°C) 5-day CRI from continuous data	Upper Ngaruroro and Upper Tūtaekurī Rivers	≤ 22°C (A band)	Ecosystem health	≤1°C increment compared to reference condition	Cox-Rutherford-Index from continuous measurements, hottest 5 consecutive days, all flows
	Lower Ngaruroro and Lower Tūtaekurī Rivers	≤ 23°C (B band)		≤2°C increment compared to reference condition	
	Ngaruroro and Tūtaekurī Tributaries, Lowland tributaries	≤ 22°C		(needs further investigation)	

SCHEDULE 3: PRIORITY CATCHMENTS

This schedule sets out the list of priority catchments or places where

2. Risk of sediment loss is higher than 500t/km^2/year (as modelled by SedNet)
3. SOE monitoring shows the freshwater objectives for nitrate concentrations for water quality are not being met
4. Probability that dissolved nutrients do not meet freshwater objectives for nitrogen (as modelled by SOURCE and using Overseer data)
5. The level of dissolved oxygen (specific for lowland streams with slope <2 m/km)
6. There is a Source Protection Zone

The priority order assigned in relation to each of these water quality issues is as follows;

	High priority	**Medium priority**	**Low priority**	**Long term**
Sediment yield (SedNet)	>500 t/km^2/year	350 - 500 t/km^2/year	250 - 350 t/km^2/year	<250 t/km^2/year
TN concentrations (all flows, median)	> 2 mg/L	> 1.2 mg/L	> 1 mg/L	<1 mg/L
TN yield (modelled) (all flows, average per sub-catchment)	> 10kg/ha/yr	> 3.5 kg/ha/yr	> 1.2 kg/ha/yr	≤1.2 kg/ha/yr
Dissolved Oxygen levels Class A streams (and /or where stream gradient <2m/km	anoxia (periods of little or no oxygen)	< 3 mg/L daily minimum and/or DO saturation <30%	< 4mg/L daily minimum and/or DO saturation < 40%	< 6 mg/L daily minimum and/or DO saturation <60%

Catchment maps will be prepared to show where priority areas are as part of the Implementation Plan. The thresholds for priority are unlikely to change significantly while the status of catchments will change as work is completed within the catchment.

Farm Environment and Catchment Collective Plans and Industry Programmes are to be completed in the following priority order; High, Medium and Low Priority over the first 3, 6 and 9 years respectively following <the operative date> of the plan (although work can commence at any time and farmers will be encouraged to start with their own programme as soon as possible).

Appendix C Guidelines and numeric values summary

attribute	value	source	guideline context / band	numeric value	stats
Clarity	Trout fishery	Hay et al. (2006)	Outstanding trout fishery	> 5m	median, <med flows
			Other significant trout fishery	>3.75m	median, <med flows
Clarity	Recreation	ANZECC (2000)		> 1.6m	not specified
Turbidity	Trout fishery	Hay et al. (2006)	Outstanding trout fishery	0.5 NTU	median, <median flows
			Other significant trout fishery	0.7 NTU	median, <median flows
	Ecosystem health	ANZECC (2000)	Statistical default guideline for upland rivers	≤ 4.1 NTU	not specified
			Statistical default guideline for lowland rivers	≤ 5.6 NTU	not specified
Deposited sediment	Ecosystem health	Clapcott et al. (2011)	Biodiversity (MCI)	< 20%	not specified
	Trout fishery		Salmonid spawning habitat	< 20%	not specified
	Recreation		Amenity	< 25%	not specified

attribute	value	source	guideline context / band	numeric value	stats
Algae biomass	Ecosystem Health	MfE (2017a)	A - Rare blooms (details in document)	≤ 50 mg Chla/m^2	biomass and frequency (1 per avge year= 8% of samples = 92nd %ile, min 3 years)
			B - Occasional blooms	>50 and ≤ 120 mg Chla/m^2	
			C - Periodic short-duration nuisance blooms	>120 and ≤ 200 mg Chla/m^2	
			D - Regular and/or extended duration nuisance blooms	>200 mg Chla/m^2	
Algae cover	Recreation	Matheson et al. (2016)	Aethetics/recreation	<30% PeriWCC	long-term annual maxima - average min 3 years
Algae cover	Ecosystem Health	Matheson et al. (2016)	Ecological condition excellent	<20% PeriWCC	long-term annual maxima - average min 3 years
			Ecological condition good	<40% PeriWCC	
			Ecological condition fair	<55% PeriWCC	
			Ecological condition poor	≥55% PeriWCC	
Phormidium	*alert, not objective. See separate table.*			*<20% cover*	*Maximum*
Macrophytes volume	Ecosystem Health	Matheson et al. (2016)	Ecological condition / flow conveyance / recreation	≤ 50 % CAV	long-term annual maxima - average min 3 years

attribute	value	source	guideline context / band	numeric value	stats
Macrophytes volume	Trout fishery/ angling	Matheson et al. (2016)	Excellent trout fishery/angling	<10 % CAV	long-term annual maxima - average min 3 years
			Good trout fishery/angling	<20 % CAV	
			Fair trout fishery/angling	<30 % CAV	
			Poor trout fishery/angling	≥30 % CAV	
MCI	Ecosystem Health	Stark and Maxted (2007)	Excellent	>119	long-term median, all flows
			Good	100-119	
			Fair	80-99	
			Poor	<80	
DIN	Algal growth - recreation <30% algae cover	Matheson et al. (2016)	Very low risk	<0.05 mg/L	long-term mean, all flows
			Low risk	0.05 to <0.15 mg/L	
			Moderate risk	0.15 to < 0.3 mg/L	
			High risk	>0.3 mg/L	

attribute	value	source	guideline context / band	numeric value	stats
DIN	Algal growth - benthic biodiversity	Biggs (2000)	Chl*a* ≤50 mg/m^2 for 20 day accrual period	<0.02 mg/L	long-term median, all flows
		Biggs (2000)	Chl*a* ≤50 mg/m^2 for 30 day accrual period	<0.01 mg/L	
	Algal growth - angling interest	Biggs (2000)	Chl*a* ≤120 mg/m^2 filamentous Chla ≤200 mg/m^{2}diatoms (20 day accrual period)	<0.295 mg/L	
		Biggs (2000)	Chl*a* ≤120 mg/m^2 filamentous Chla ≤200 mg/m^{2}diatoms (30 day accrual period)	<0.075 mg/L	
	80th percentile of upland rivers	ANZECC (2000)	Statistical default guideline for upland rivers	<0.167 mg/L	long-term median, all flows
	80th percentile of lowland rivers		Statistical default guideline for lowland rivers	<0.444 mg/L	
DRP	Algal growth - recreation <30% algae cover	Matheson et al. (2016)	Very low risk	<0.003 mg/L	long-term mean, all flows
			Low risk	0.003 to <0.006 mg/L	
			Moderate risk	0.006 to < 0.015 mg/L	
			High risk	>0.015 mg/L	

attribute	value	source	guideline context / band	numeric value	stats
DRP	Algal growth - benthic biodiversity	Biggs (2000)	Chlorophyll *a* ≤50 mg/m^2 ; 20-day accrual period	<0.001 mg/L	long-term median, all flows
			Chlorophyll *a* ≤50 mg/m^2 ; 30-day accrual period	<0.001 mg/L	
	Algal growth - angling interest		Chlorophyll *a* ≤120 mg/m^2 filamentous Chlorophyll *a* ≤200 mg/m^{2}diatoms; 20-day accrual period	<0.026 mg/L	
			Chlorophyll *a* ≤120 mg/m^2 filamentous Chlorophyll *a* ≤200 mg/m^{2}diatoms; 30-day accrual period	<0.006 mg/L	
DRP	80th percentile of upland rivers	ANZECC (2000)	Statistical default guideline for upland rivers	<0.009 mg/L	long-term median, all flows
	80th percentile of lowland rivers		Statistical default guideline for lowland rivers	<0.01 mg/L	
DRP	Algal growth, instream habitat	HBRC (2006b) (RRMP)		<0.015 mg/L	long-term median, flows < median
E. coli	'Swimmability'/ Human Health for recreation	MfE (2017a)	Amended, guidelines changed over the time of the TANK stakeholder group process. See Appendix D.		
Ammonia	Toxicity	MfE (2017a)	A - 99% spec protection, no effect on any species	≤0.03 / ≤0.05 mg/L	annual median / annual max

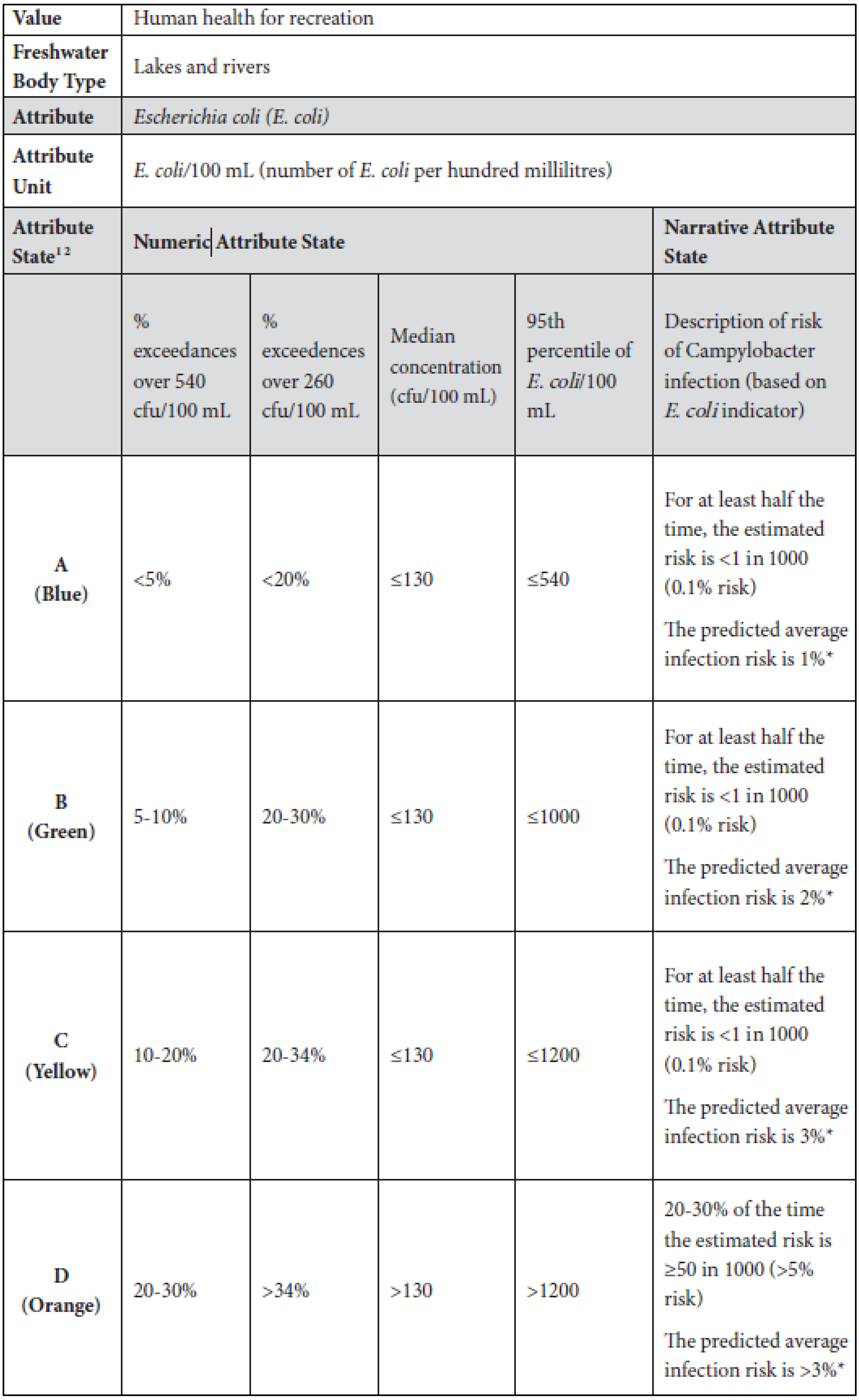
attribute	value	source	guideline context / band	numeric value	stats
			B - 95% spec protection, starts impact on 5% most sensitive spec	≤0.24 / ≤0.4 mg/L	
			C - 80% spec protection, reduced survival of most sensitive species	≤1.3 / ≤2.2 mg/L	
			D - Starts approaching acute impact level for sensitive species	>1.3 / >2.2 mg/L	
Nitrate	Toxicity	MfE (2017a)	A - unlikely to be effect on any species, high conservation value	≤0.03 / ≤0.05 mg/L	annual median / 95th %ile
			B - some growth effects on 5% most sensitive spec	≤0.24 / ≤0.4 mg/L	
			C - growth effects on up to 20% species, no acute effects	≤1.3 / ≤2.2 mg/L	
			D - Impact on growth of multiple species, approaches acute impact level	>1.3 / >2.2 mg/L	
Dissolved oxygen	Ecosystem Health	MfE (2017a)	A - No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.	≥8.0 / ≥7.5 mg/L	7-day mean min / 1-day min
			B - Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.	≥7.0 and <8.0 / ≥5.0 and <7.5 mg/L	

attribute	value	source	guideline context / band	numeric value	stats
			C - Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.	≥5.0 and <7.0 / ≥4.0 and <5.0 mg/L	
			D - Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.	<5.0 / <4.0 mg/L	
Temperature Regime	Ecosystem Health	Davies-Colley et al. (2013) Eastern Dry Regions	A - No thermal stress	≤19°C	Cox-Rutherford Index
			B - Occasional thermal stress, particularly sensitive specs	≤21°C	
			C - Some thermal stress on occasions, some sensitive specs lost	≤25°C	
			D - Significant stress, loss of ecological integrity	>25°C	
Temperature Regime	Ecosystem Health	Davies-Colley et al. (2013)	A - No thermal stress	reference temperature	Cox-Rutherford Index

attribute	value	source	guideline context / band	numeric value	stats
		Temperature increments compared to reference site	B - Occasional thermal stress, particularly sensitive specs	≤ 1°C increment compared to reference site	
			C - Some thermal stress on occasions, risk sesitive specs lost	≤ 2°C increment compared to reference site	
			D - Significant stress, loss of ecological integrity	≤ 3°C increment compared to reference site	

Appendix D Attribute *E. coli* – human health for recreation

(MfE, 2017a)



Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	*Escherichia coli (E. coli)*				
Attribute Unit	*E. coli*/100 mL (number of *E. coli* per hundred millilitres)				
Attribute State[1,2]	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100 mL	% exceedences over 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th percentile of *E. coli*/100 mL	Description of risk of Campylobacter infection (based on *E. coli* indicator)
A (Blue)	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%*
B (Green)	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%*
C (Yellow)	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%*
D (Orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%*

Appendix E Document review

Comments by peer reviewer Dr Roger Young (Cawthron Institute)

	Chapter	Comments from Dr Roger Young	Comment from the author	Action
1	1.2.4.	See comment in review letter – why are catchments FMU's and not the four stream types?	See response to comment (II) in review letter	
2	1.2.5.	See comment in review letter. What about the other national values listed in the NPS-FM. Were they all considered? Are they all relevant and included? Were some not relevant (e.g Hydropower) and therefore excluded?	See response to comment (I) in review letter	
3	1.2.5.	I was left wondering what the RIVAS group identified. Is this outlined in the following paragraphs? If so, seemed like a disappointing outcome if discussion on state and objectives could not be held due to a lack of information.	A high-level summary on the RIVAS group outcome is given in the following paragraphs. For more detail please refer to the Cawthron report as cited in the text.	Changes made to the text with some more detail on the process used to identify values.
4	Figure 1-7	Should physical habitat structure be an attribute for assets/property/other if river stability and river gravel are key values? Also surprised that fish and cyanobacteria attributes are missing from the social/cultural/recreational slice.	Physical habitat structure, fish and algae (including cyanobacteria) are attributes under ecological values, but also relate to other values (e.g. recreational, cultural values, river gravel management, or human health (cyanobacteria). Attributes are generally only identified under one critical 'key' value preferably where guidelines exist, but will have to be managed under all aspects of potential impact / management of other values. Attributes are not repeated under all values they also relate to.	No changes made
5	Table 1-3	This table seems incomplete. Why is clarity not considered important for ecosystem health? Why are dissolved nutrients and toxicants not related to estuary health? Why are macrophytes not related to anything?	Agree, the table was incomplete	Table amended

	Chapter	Comments from Dr Roger Young	Comment from the author	Action
6	Table 2-2	Or <10% change compared to reference [for deposited sediment] Worth adding?	This guideline wasn't included because currently we do not have the reference condition for deposited sediment in the TANK catchments, nor for similar FENZ classes in Hawke's Bay. Due to time limitations, guidelines lacking data were not discussed in the TANK Group.	No changes made
7	2.1.2. Periphyton and cyanobacteria	See comment in review letter about the importance of avoiding accumulations of toxic scums, even if cover is below 50%.	See response to comment (III) in review letter	
8	2.1.6. Temperature Table 2-8	See comment and suggested change in wording in review letter. I don't think these narrative descriptions are appropriate if there might naturally be thermal stress occurring in the height of summer. Any change in stress needs to be relative to that occurring naturally.	Useful comment. The table and narrative descriptions are cited from the report on proposed NOF thresholds (Davies-Colley *et al*. 2013). But this issue can be brought up in the text.	No change to table. Added comment to paragraph 2.1.6.
9	2.1.6. Temperature	Yes, this stuff is tricky!! These aren't great reference sites for hill country tribs, lowland streams or even the lower mainstems – but probably the best available!!. See comments in the review letter. I am concerned that you might be setting unrealistic temperature thresholds given naturally hot and dry climate that will be impossible to meet.	See response to comment (IV) in review letter	
10	2.1.6. Table 2-10	For the other attributes you have different criteria for each water quality area. Davies-Colley proposed two levels for all of NZ (Maritime and Eastern Dry), but they did say they were tempted to split upland and lowland too. You could think about having different criteria, although it's tricky to know what numbers to use for each.	*I read the document as: separate NOF criteria should be developed for upland and lowlands streams, and discussion on this is encouraged. But until then the authors of the document recommend to use one set of thresholds for upland and lowland rivers after considering the thermal inertial provided by forested catchments under reference condition would mitigate the effects of a decrease in altitude (p.33 in Davies-Colley et al. 2013).*	Amended text to explain gaps and limitations of thermal thresholds as proposed in the NOF discussion document, including the lack of reference temperatures for lowland streams.
11	2.1.6. Temperature	Are they common, or just a few stragglers washed in from nearby cool tributaries? If just stragglers then this isn't good evidence to say that temperature can't be a limiting factor.	2 Plecoptera taxa common to very abundant over 10 years, 2 taxa low in numbers and inconsistent findings, may be stragglers	Deleted paragraph it as does not provide enough useful information for discussions on temperature thresholds.

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12	2.2.1 Attributes values relationships	Note that these types of experiments are really only a snap shot, but still worthwhile. Key point is that managing both nutrients is key.	Agree, incomplete, unclear paragraph.	Added information and amended paragraph.
13	Figure 2-2	Should the top left figure say suspended sediment, not deposited sediment?	Agree, I used one title for several slides when explaining different sediment forms in water, and it would have been clearer to change each title specifically to every single slide for later reference.	No change to figure as these are the original slides that were discussed with the TANK Group. Amendments to figure legend.
14	Figure 2-4	Should flow be changed to flow conveyance? Otherwise ticks don't make sense.	Agree. Would have been clearer. The meanings for 'flow' and 'flow management' were explained in the presentation.	No change to figure as these are the original slides that were discussed with the TANK Group. Amendments to figure legend.
15	2.2.1. Attributes Values relationships	Probably, but depends on what management methods are used.	Agree	Text amended
16	Appendix D Proposed PC9 objectives Turbidity and Clarity	*Turbidity Ngaruroro and Tūtaekurī ≤0.41NTU:* This doesn't seem to be right. Error or am I missing something? If intentional then the turbidity targets are inconsistent with clarity targets which is a problem. / Is it a statistical guideline. I'd say trout fishery based on Hay et al.	Yes, the targets for clarity and turbidity are inconsistent. The TANK Group identified trout fishery as a value for the upper catchments of the Tūtaekurī and Ngaruroro, whereas the tributaries and the lowland areas were to be managed for recreation and ecosystem health. In meeting 39 the TANK Group discussed the ANZECC guideline of >1.6m clarity for recreation: this was not seen as sufficient to also protect Kaitiakitanga in water management areas 2 and 3. As a pragamatic solution it was suggested to take the threshold of ≥3.75m clarity for significant trout fishery as a higher protection level instead of the ANZECC guideline ≥1.6m. Therefore the value-to-threshold relationship is not consistent, nor the clarity-to-turbidity relationship.	Paragraph added in Chapter 2.1.1. to explain this.

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	Appendix D Proposed PC9 objectives Periphyton cover	Why have two different periphyton cover objectives? Surely just pick the most precautionary one and therefore protect both sets of values.	Agree. The upper Ngaruroro and Tūtaekurī the objective for excellent ecosystem health is the most precautionary guideline, and for the rest of the management areas the periphyton objective for recreation is most precautionary one (good ecosystem health ≤40% (matching objective good state for these management areas) vs recreation good ≤30% cover.	Changes made to table.
	Appendix D Proposed PC9 objectives Cyanobacteria	Include avoid accumulations along the river margins as highlighted in cyano guidelines	There are currently no attribute guidelines in relation to detached cyanobacteria accumulations on river banks. The public health risks of detached algal mats need to be addressed through good public information processes. See also comment III review letter.	No changes made to table.
	Referring to	Comments in review letter		
I	1.2.5. Values in the TANK catchment	I did wonder about the limited discussion of the 'other' national values that are described in the National Policy Statement for Freshwater Management 2014 (updated 2017). These values include natural form and character, mahinga kai, fishing, irrigation, cultivation and food production, animal drinking water, wai tapu, water supply, commercial and industrial use, hydro-electric power generation, transport and tauranga waka. Many of these values have been captured through the TANK process, but it would be good to see a section specifically noting that all of these have been considered and which ones have been included or excluded.	The identification of values started in 2012 (before the NPS_FM (2014) was released). Discussion on values was an iterative process over several years. River values assessment system, several meetings and workshops on values, a critical values approach, were methods used in the process. Listing the discussion outcome of every value, including the non-compulsory NPS-FM values, is outside the scope of this report. It can be referred to in the reports and meeting records for further details. Instead, a summary on the relevant values the TANK Group identified for PC9 is given in Figures 1-7 and 1-8.	Information added regarding more detail and information on the process how values were identified and prioritised, but a collation of all values that were discussed was seen as out of scope for this report. More details on values of the TANK group can instead be taken from meeting records and the reports listed in the paragraph.

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II	1.2.4. FMUs and ecological surface management areas	I found the description of the freshwater management units somewhat confusing with catchments being defined as freshwater management units (page 16) but all the objectives in the report being related to the 4 water quality areas (upper catchments, mid-low mainstems, hill country tributaries and lowland tributaries). The four water quality areas identified make good sense to me, but I am left wondering why these aren't called freshwater management units. Maybe there's a good planning reason?	Agree that a better explanation for the reasons behind establishing ecological management areas and FMUs as separate management units is required.	Changes made to the text to explain the derivation of ecological management areas and FMUs, and the planning reasons for this.
III	2.1.2. Periphyton and cyanobacteria	The discussion of the interim cyanobacteria guidelines (MOH 2009) focusses on the cover limits but overlooks the reference to concerns when potentially toxigenic cyanobacteria are visibly detaching from the substrate, accumulating as scums along the river's edge or becoming exposed on the river's edge as the river level drops, even if cover levels are less than 50%. In my opinion, an important objective is to avoid these accumulations of potentially toxic scums, as well as maintain cover levels below 50%.	While the attribute and freshwater objective focuses on cyanobacteria cover, the public health risks from detached scums will need to be addressed. The accumulations of algae that may detach are in part being managed by objectives that seek to limit algae cover. There are currently no attribute guidelines in relation to detached cyanobacteria accumulations on river banks. The public health risks of detached algal mats need to be addressed through good public information processes.	Additional information in paragraph.

IV	2.1.6. Temperature	The temperature objectives were based on comparison with reference sites rather than using the proposed NOF limits for the Eastern Dry region. I generally like the use of the reference site approach because it takes into account local information, but note that the upper reaches of the Ngaruroro and Tūtaekurī are not good reference sites for the hill country tributaries or lowland tributaries. Of course, there are no unmodified streams in these areas to act as ideal reference sites, so the upper reaches are perhaps the best available. The hill country tributaries might be narrower and more shaded than the larger upper reach mainstem, and therefore cooler than reference, or on the other hand draining lower altitude areas and therefore warmer than reference. Similarly, water temperatures in the lowland tributaries may be strongly influenced by groundwater inputs and therefore naturally cooler than reference (in the summer) or draining low altitude areas and therefore naturally warmer than reference. There are even some questions about whether the upper reaches of the Ngaruroro and Tūtaekurī are an appropriate reference for the mid-lower reaches of the Ngaruroro and Tūtaekurī. With air temperatures generally decreasing with altitude (about 6 °C per 1000 m) you would naturally expect higher temperatures in the lower reaches of the Ngaruroro and Tūtaekurī near sea-level than at the reference sites, which are at about 460 m and 340 m above sea level, respectively. These differences in air temperature are probably also likely reflected in differences in water temperatures. In my opinion, these natural differences in temperature need to be taken into account in the objective setting. In relation to the temperature guidelines, if the reference site approach is used then I think the narrative attribute state needs to be modified to reflect that the assessment is compared to reference and not absolute. For example, a < 1 °C increment in temperature might result in thermal stress if the natural temperature regime is already stressing sensitive aquatic life. The narrative could perhaps be changed to < 1 °C will result in no further thermal stress	I agree with all points, (some were also mentioned and discussed in the document). This comment highlights the lack of suitable regional and stream/river type specific thresholds for temperature, and the lack of knowledge regarding reference temperature conditions for lowland streams. The authors of the NOF proposed temperature threshold document (Davies-Colley et al., 2013) encourage the discussion on separate upland and lowland criteria, but recommend the use one set of thresholds for upland and lowland rivers after considering the thermal inertial provided by forested catchments under reference condition would mitigate the effects of a decrease in altitude. In forested catchments the thermal inertia of shaded upstream waters would mitigate the effects of a decrease in altitude to some extent. Thermal regimes of many lowland rivers are elevated as a result of widespread deforestation and are not representative of reference site conditions (Davies-Colley et al., 2013). Dr. Young highlights that by using only the upland sites as reference condition for all four TANK ecological areas might mean setting unrealistic temperature thresholds that will be impossible to meet given the naturally hot and dry climate in Hawke's Bay. I suggest keeping the thresholds derived from increments from reference condition as in the document, but using them as guidelines to review and adapt as science	Significant changes to the text with more detail on uncertainties in temperature threshold setting in the discussion. Changes to Plan Change document: Schedule 1 with temperature increments only, Schedule 2 has temperature thresholds as discussed in the group, for further investigation.

	Chapter	Comments from Dr Roger Young	Comment from the author	Action
		compared to that expected at the reference site, < 2 °C increment would result in minor further thermal stress compared to that the reference site, and so on.	catches up with lowland reference condition.	
V		Schedule 3 outlines the rationale for determining priority catchments for management action. I can understand the reasoning behind the priorities, but note that this will focus efforts on the worst catchments first. This could be appropriate, but some issues in the worst catchments may be intractable and soak up considerable resources with limited environmental benefit. Some sort of cost-benefit analysis might help with the priority setting.	There is not much point targeting places where there are no problems. Where there are problems we have identified actions to fix them (e.g. a specialist group looking at solutions for the Karamū ; in pastoral catchments focus on sediment control (as modelled by Sednet), - wetland protection/development and stock exclusion leading). There is a specific management focus in priority areas, the milestones are not specified for specific locations – but our priority location focus will mean resources are directed there first. We specifically didn't make nitrogen reduction a focus in milestones and rules because of our uncertainty about how much reduction was needed and its potential impact on ecosystem health in Karamū anyway.	No changes made.