15 September 2009 Ref : NRRP/2002/V1/NOT/HEA/12C

MEMORANDUM

FROM : ADRIAN MEREDITH, MICHELE STEVENSON, (WITH CONTRIBUTIONS FROM SHIRLEY HAYWARD)

TO : BRENT COWIE, NRRP HEARING PANEL 1

CC

SUBJECT : RESPONSE TO QUERIES RE SURFACE WATER QUALITY OBJECTIVES IN OFFICER REPORT 12A

In a Memorandum to John Glennie, dated 25 May 2009, you requested further information on a number of matters relating to the recommendations and advice provided to you in Officer Report 12A, and in particular the supporting information in the technical report that reviewed the proposed NRRP water quality objectives and standards (Hayward *et al.* 2009). You also requested that further consideration be given to some of the proposed targets and outlined a range of statements and specific questions, to which we have responded after the introductory comments below, in the order that these are posed in the Memorandum.

We are also aware of a number of additional associated and different questions that you posed during the hearing of submissions, which were subsequently relayed to us by planning staff. Where possible we have identified those additional questions and answered them in association with the relevant questions posed in the Memorandum.

Introduction

In considering the questions posed, we acknowledge the principles that you have decided to frame your decisions on, as stated in your Memorandum, and initially comment on these as part of a general introduction to our response. We also provide further discussion of some key concepts that we believe are important in understanding the intent of the water quality objectives, in particular.

- ***The outcomes or targets set for surface water quality management need to provide for improvement where water quality is currently degraded.***

  We strongly endorse this principle. It has formed the basis of many of our recommendations for water quality objectives, particularly relating to degraded water bodies, such as spring-fed streams on the plains, urban streams and coastal lakes (see third paragraph of Chapter 7 of the technical report). The purposes for management and identification of critical values were a fundamental consideration when deriving the recommended changes to the objectives in OR12A, i.e. the desired outcome is linked to the key values or services provided by the water body.

- ***Improvement must be within the framework of outcomes that are realistic and reasonably achievable.***

As is stated in the third paragraph of Chapter 7 of the technical report, the recommended numeric objectives for degraded water bodies are considered achievable, but not necessarily immediately. We also describe them as “aspirational but achievable” in the introduction to Chapter 7. Timeframes for achieving the objectives will vary between rivers and lakes, depending on current state and pressures as well as the management approaches that are implemented. The plan makes a clear distinction between objectives, which are intended to portray a desired outcome that extends beyond the life of the current plan, and the Anticipated Environmental Results (AER) (section 4.10) which sets out what the plan expects to achieve within 10 years of the Chapter becoming operative, i.e. a measure of progress toward achieving an objective.

This difference is illustrated in Figure 1, which provides a theoretical example of three different spring-fed Plains streams. Stream A is a high quality stream that has a healthy ecosystem and already achieves the objective most of the time (such as say reaches of the Cust River or Ealing Springs stream). Stream B is moderately degraded, but with implementation of appropriate management initiatives identified by a specific work programme (Environmental Result WQL2a) it improves quickly and achieves the objective by the time the plan is due for review (may apply to Harts Creek or Waikuku Stream, for example). Stream C is highly degraded and despite the implementation of a work programme, the management initiatives take longer to realise an improvement in the water quality and health of the stream (may apply to the Cam River or Silverstream, for example). At the time of the plan review, management activities in the catchment of Stream C are reviewed, changes are made and more rapid improvement in stream health follows. A key point is that the numeric objectives provide a target or reference point toward which improvement will be directed. Success of the plan should not be judged as a ‘pass’ or ‘fail’ based on whether the objectives have been reached by a particular point in time. Instead the objectives provide guidance as to the state of instream health (water quality and ecosystems) that ECan is seeking to ensure that rivers, streams and lakes can provide to meet a range of values into the future. Furthermore, the objectives provide a more rational way for Council to allocate its resources when considering current and future work programmes under the Long Term Council Community Plan.

In the technical report, we recommend that it may be appropriate to include policies in the plan that acknowledge and allow for longer timeframes for achieving certain water quality objectives. The important point is that activities should be focussed on improving the state of degraded water bodies with the desired outcome set at a level that supports the key values of the water body.

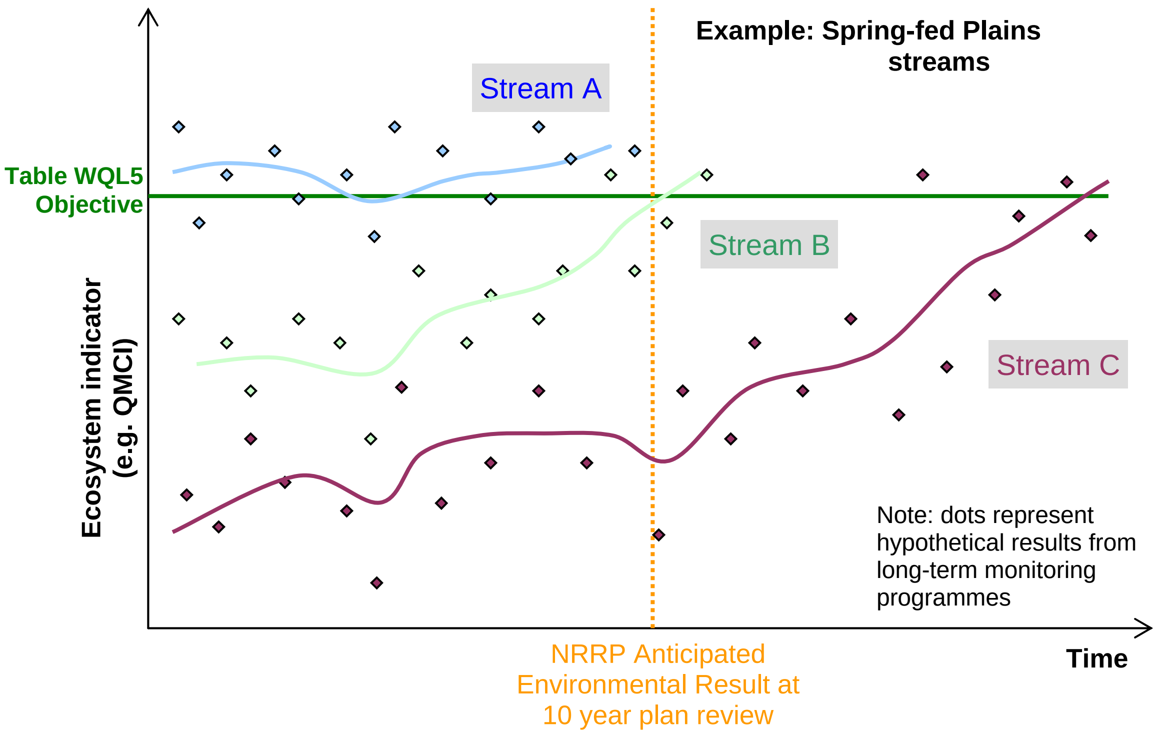

Figure 1 **Illustration of varying timeframes for achievement of objectives**

- ***The outcomes set must be able to be reasonably influenced by management tools available to Environment Canterbury.***

We agree with this principle, and emphasise that there are a wide range of activities that can impact on water quality and therefore a wide range of management tools that can be used to influence water quality outcomes. As is stated in the fourth paragraph of section 1.3 of the technical report, the water quality objectives reflect the combined effects of all activities that affect water quality and ecosystem health, including point-source discharges, land use and associated non-point sources of pollution, water takes, dams, diversions and works in lake and riverbeds.

Management of point-source discharges through implementation of the receiving water quality standards is therefore just one of many methods for working towards achieving the water quality objectives. An example is the setting of flow regimes, which directly and indirectly influence instream characteristics, such as temperature, dissolved oxygen, benthic invertebrate communities (QMCI), substrate composition (fine sediment cover) and bed stability (macrophytes and periphyton). There are clear linkages between Chapters 4 and 5 of the plan, particularly through Policy WQN3 which requires that flow and level regimes should be set to meet the requirements of Objective WQL1.1. Staff have recommended a new Policy WQLX (Effects on water quality and river bed characteristics caused by a change to the flow of a river) to make a direct link between changes to a flow regime and water quality. The numeric objectives recommended for Objective WQL1.1 (in Table WQL5 and Table WQLAA) assist the flow regime assessment process by providing clear direction as to the water quality and ecosystem outcomes sought for the different types of rivers, streams and lakes found in the region.

The plan includes a mix of regulatory and non-regulatory methods to implement the plan policies. With regard to non-point sources of contaminants, the methods are primarily non-regulatory, for example working with individuals and communities to develop water care programmes, property plans and riparian management strategies. It is our understanding that a project is underway to review the current approaches to managing non-point source discharges.

The influence of natural perturbations

When thinking about achievability of objectives and the management tools available to ECan it is important to make a clear distinction between natural influences and those that have an anthropogenic (human-induced) origin. The concept of "natural perturbations" is embedded in RMA water quality classes, and we recognise and accept that there are factors that influence the indicators used in the water quality objectives that are, at a regional level at least, beyond human control. One critical factor is climatic variability, with precipitation having an obvious and significant impact on flow variability. Both floods and droughts strongly influence water quality and ecosystems in aquatic environments. With respect to human activities, however, there are always different approaches that can be taken to achieve different outcomes and therefore management tools should be available to address the majority of anthropogenic influences. We accept, and expect, that natural perturbations will cause the water quality objectives to not be met occasionally over a period of time and consider that management activities should be focussed on ensuring that anthropogenic factors do not contribute to *increasing the frequency of [natural] non-compliance* with the objectives.

It is also important to consider natural perturbations when examining water quality data to compare the existing state of Canterbury rivers with the recommended water quality objectives. This is a theme that will emerge in several of the responses to the questions posed by the Panel. There is a high degree of natural variability in the indicators used to describe the condition of rivers, streams and lakes that we monitor, and for that reason it is necessary to establish a sufficiently large data set to be able to describe the general state of a particular water body. The distribution of data collected is highly likely to include a number of outliers that are a result of abnormal conditions or natural perturbations, such as sustained low flows during a drought, or high flow in flood times. While these outliers should be acknowledged and the reasons for them identified, it is typical practice to either exclude them when reporting on the water quality state, or allow for a small percentage of them (the percentile approach in ANZECC (2000)) and other modern guidelines and standards). Natural environmental systems are adapted to be resilient to a small incidence of such outliers or extremes. We believe the purpose of a plan objective is to avoid or prevent significant *increases* in the frequency of these incidences as a result of anthropogenic effects.

While the concept of natural perturbations is embedded in water quality management there remains the challenge to distinguish between natural perturbations and what is an unreasonable anthropogenic effect. Guidelines such as ANZECC (2000) and the MfE/MoH (2003) Recreational Water Quality Guidelines use a percentile exceedance approach largely to acknowledge natural variability. It should however not be confused with allowing such percentile exceedances to always occur as a result of anthropogenic activities, because these sets of exceedances can become additive and excessive.

Management tools

There are a wide range of management tools available to Environment Canterbury that can be developed into river/lake-specific programmes to improve the state of degraded waterways. At a broad level, these include working with industry and the community, education and promotion of sustainable management practices and techniques, providing funding for direct intervention, identifying sensitive areas, resource consents, and compliance monitoring and enforcement. The concept of adaptive management is highly applicable to surface water quality management, as approaches can be readily modified over time if monitoring indicates that the management measures are not resulting in the desired level or rate of improvement.

It is also important to recognise that there is a significant amount of ongoing research being undertaken around the country in the field of surface water quality management. Knowledge and understanding of river and lake systems and the links between their state, pressures on them and management responses is increasing rapidly. The range of management tools available and expertise surrounding their use and appropriate implementation will continue to grow, thereby enhancing the scope for improvement in the instream health of our waterways. New advances in research, management and mitigation measures developed through the life of the plan will also aid progress toward achievement of objectives.

Air quality example offers a useful analogy

The objectives, target and monitoring used in NRRP Chapter 3 (Air Quality) for particulate air pollution (PM_{10}) is a good example of the points discussed above. It illustrates how what appeared to be an intractable problem was resolved in part by setting measurable objectives thereby providing an effective way for the Council to measure its performance.

Air quality (particularly PM_{10} concentrations) in Christchurch and other degraded airsheds is to be improved to target levels over the life of the plan (2013) and beyond. The targets are proposed to be achieved by a mix of regulatory and non-regulatory measures, e.g. Clean Heat subsidies, and rules. However, one key feature of air quality degradation is its highly variable and seasonal nature. Targets are therefore set as straight line path trends containing within them the ‘annual second highest daily median concentration’. This novel approach of setting a target also gives effect to air quality national environmental standards (NES) and emphasises the importance of aiming to achieving an outcome.

Objective water quality targets are not dissimilar to air quality and inherently exhibit similar multiple causes of degradation and high variability. Similarly, the reasons for requiring improvement, and the likely time course for achieving such improvements can be quite lengthy. A key feature is that target outcomes should be clearly signalled and it is acknowledged that frequently they may not be achieved ‘overnight’.

Reporting on objectives

Another issue that has been touched on in the above discussion is how progress towards achievement of the objectives will be monitored and reported on. The water quality objectives are overall outcomes for a river or lake that will be assessed over a period of time by state of environment monitoring, and not by using small data sets or on a case-by-case basis for specific activities. The intention is that assessment will be at the catchment or river scale and will be based on Environment Canterbury’s long-term water quality and ecosystem health monitoring programmes. A review of the existing monitoring programmes is planned to ensure that these will provide an adequate quantity of appropriate information into the future for this purpose.

Summary

The following key general points provide context for the specific responses below:

- Timeframes for achieving water quality objectives will differ among water bodies depending on current water quality, pressures on the resource, and the management approaches that are taken. The Chapter distinguishes between the expectations for the objectives and the environmental results that are anticipated within the 10-year lifetime of the plan.
- The water quality objectives reflect the combined effects of all activities that affect water quality and ecosystem health. Therefore, management approaches need to consider factors ranging from point source discharges to land use with associated diffuse sources, water takes, dams, diversions and works in riverbeds.
- Both regulatory and non-regulatory methods are available to Environment Canterbury. It is anticipated that the range of methods will further expand as knowledge and understanding of surface water quality management issues continues to develop at local, regional and national levels.
- Natural perturbations will cause objectives to not be met occasionally. However anthropogenic factors should be managed so as not to contribute to an increase in the natural frequency of non-compliance caused by such natural perturbations.
- Assessment of progress towards achieving the water quality objectives will be informed by Environment Canterbury's state of environment water quality and ecosystem health monitoring programmes and will be undertaken at the whole river scale, i.e. not using small data sets or directly related to specific locations or activities.

Answers to specific questions relating to classes of objectives.

1. QMCI

You note that: "***We would first observe in relation to a number of these "box and whisker" plots that we do not agree with the statistical treatment of so called outliers. These are part of the range and we have treated them as such***".

The presentation of box and whisker plots is a commonly used statistical method of expressing large amounts of data and illustrating the pattern of the data distribution (e.g. Kelly *et al.* 2005, Scarsbrook & McBride 2007, Larned *et al.* 2005). Most common statistical packages that offer such presentations offer only a limited range of data summary options. All condense the data into frequency intervals. It is common practice in these packages to either portray the outer bound data (e.g. <5 % and >95%) as 'outliers' or (e.g. <1% and >99%) as 'extremes', or data outside certain confidence intervals as outliers or extremes. Both of these approaches offer a better way of illustrating outlier data than simply portraying the maximum extent of the range.

We have used this type of presentation to assist the interpretation of the data distributions, but in no way do we intend that the default terms 'outlier' or 'extreme' should be interpreted to indicate that such data were not part of the valid data set, or should be deleted. They are part of the 'currently observed range' however, it is also important to determine whether data (such as outliers and extremes) are in fact the result of 'natural perturbations' or anthropogenic effects (see introductory discussion of these concepts). Certainly high range extremes generally represent particularly 'pristine' sites or conditions (or biodiversity 'hotspots'). It is the lower range 'extreme or outlier' data that need to be treated with caution when determining whether they represent examples of natural extremes or anthropogenic degradation.

You ask:

Q1. We would like some further information for each of these categories what types of sites are towards the lower levels of these ranges and for what possible reasons.

Below are brief further descriptions of the lower range data for the listed river types.

Banks Peninsula

There are no 'outliers' noted for this category, therefore these comments relate to the lower quartile (roughly any QMCI value of less than 4.4) of the data range in general. The full data set has been collected from a total of 63 sites (Table 2.2, pg 24 of the technical report) with a varying number of observations made at each site. The lower quartile of the data comprises 74 observations made at 24 different sites. Of this sub-data set, seven sites have only been sampled on one occasion, as part of a scoping exercise, making it difficult to explain why the QMCI values at these seven sites are low or whether they are routinely low.

The remaining sites, from which there is more than one observation, are largely situated in the lower reaches of streams with little gradient and are therefore most susceptible to the cumulative effects of the catchment land use upstream. Compared with sites situated in the upper reaches of Banks Peninsula streams, the sites in the lower reaches generally have;

- less riparian margin,
- more stock access,
- less shading,
- higher sediment deposition (due to lower gradient),
- higher sediment load (due to accumulation).

These site characteristics, combined with the natural susceptibility of Banks Peninsula to periods of very low flow and high temperatures mean that the macroinvertebrate communities can be subjected to some harsh environmental conditions. The frequency of occurrence of these harsh conditions is dependant on the prevailing climatic conditions. Macroinvertebrate communities at sites with well developed and intact riparian margins are better buffered from prevailing climatic conditions and thus the conditions within the streams are more stable and consistently achieve high QMCI values.

Objectives therefore need to be set at a condition where healthy communities are indicated, but that currently such objectives are unlikely to be consistently met in more highly developed streams. Objectives will therefore indicate a requirement for greater emphasis on restoration, or on much stronger intervention on some streams to ensure they are met over the life of the plan.

Hill fed-Lower

These comments relate to the lower quartile of the data set (QMCI values less than 5). The full data set has been collected from 98 sites, with a total of 530 observations. The lower quartile comprises 139 observations from 57 different sites, and 11 sites have four or more observations with QMCI values of less than 5. A number of the sites with values in the lower quartile were sampled at the start of the Ecosystem Health Monitoring programme (1999/00 and 2000/01) and have not been sampled since. This makes it difficult to interpret reasons for low QMCI values or their likely consistency of low values.

Of the sites in the lower quartile, four have consistently shown poor QMCI values. One site (Raincliff Stream) is known to be generally degraded. This stream passes through unusual geological strata in places (limestone and mudstone) and is located in an area of intensive agricultural land uses. Many reaches are open, poorly shaded, freely accessed by stock, and are sluggish or slow flowing for much of the year. The other three sites are more typical of gravel hill fed streams and have shown a general improvement over the last 3-4 years. There has been little change in the measured habitat conditions to explain this so it is likely to result from improved seasonal flow conditions and/or improved water quality, both as a result of recent favourable climatic conditions.

Sites in the lower reaches of hill fed streams, similar to most stream types in their lower reaches, are subjected to the cumulative impacts of upstream land use. The streams commonly increase in width and become shallow, resulting in higher daily temperature peaks and ranges. The land use surrounding the lower reaches of hill fed streams is generally intensive agriculture. This frequently results in a lack of riparian vegetation resulting in little stream shade, little input of woody debris and consequently limited instream habitat heterogeneity. Many of these habitat features can be improved by a number of advocacy mechanisms promoted by Resource Care and Planning initiatives. Examples of these are the river type information booklets produced by resource care and the Riparian Management Classification (RMC) and scoring protocol developed by NIWA for broad council use and promotion. Implementation and promotion of these and other initiatives would be expected to help increase habitat condition and QMCI levels to the target levels set by the objective.

Hill fed-Upland

The lower quartile for this category comprises 48 observations from 19 sites, from a complete data set of 187 observations from 26 sites. These figures alone indicate that this river type is very dynamic. Of the sites in the lower quartile, four show consistently poor QMCI values. The four sites are very different in character. Blue Duck Stream (at the base of the Seaward Kaikoura range) is steep and bouldery in its lower reaches, with highly erodible banks. Upstream, it has suffered from erosion of roading and tracking and farm subdivision and development. It is also subject to very high, flashy flows and long periods of low flow. Charlie Stream and the tributary of the Stour River are situated high in the Ashburton basin; they are very unstable, with open sites on very mobile shifting gravel. For much of the year, flows are very low and shallow, with periods of flooding which cause significant changes to the sites. At these two sites, adjacent land use is unlikely to have altered greatly over time, and is not intensely developed. Riparian margins are naturally limited at these streams. The fourth site is on Omarama Stream which has little gradient, but has a deep stable flow. Adjacent land use is much more intensive and there are much higher anthropogenic stresses on the stream (including authorised but currently being reviewed sewage treatment plant discharges). Clearly, two of these sites fail to meet the objective as a result of anthropogenic stresses, and two from more natural perturbation type functions.

Spring fed-Upland

The lower quartile is made of 19 observations from six sites. The full data set is 72 observations from eight sites. Small stream type groups with few observations often display a high degree of variation in their range.

Of the sites in the lower quartile, three have consistently poor QMCI values. Slovens Stream has a number of high QMCI values (values greater than 5) and a number of lower QMCI values. This stream, like most spring-fed streams, is slow flowing with a very consistent flow. The land use adjacent to much of this stream is deer pasture. Stock has open access to the stream for drinking and wallowing and there is little tall vegetation to provide shade. Deer in particular have a high impact on streams as they mobilise sediment and increase bank erosion.

In a spring fed system, the flow profile (generally consistent and steady) means that fine sediment is not easily washed out of the system, with implications for sediment sensitive macroinvertebrates. The other two sites on the Quail Burn and Spring Creek are similarly open, with low summer flow. Spring Creek is now in one of the irrigated, intensively farmed areas of the Mackenzie basin and QMCI values have been declining rapidly over the past five years.

These examples illustrate that degradation largely as a result of anthropogenic stresses could be managed (avoided or mitigated) by more explicit management requirements, controls or protection mechanisms. An objective, such as QMCI, clearly illustrates effects and the need for increased active management.

Alpine-Upland

These comments are relevant to QMCI values less than 5 for this category. In total, there are 11 observations of QMCI values less than 5 from nine sites, from a total of 159 observations from 24 sites. Of the 11 observations, only two sites had more than one observation in this range.

One site, the Hope River, has a total of 12 observations and the two low QMCI scores were recorded in December 2000 and December 2008. Sampling in both years coincided with preceding early summer floods. Despite delaying sampling until 2-3 weeks after such floods, in accordance with established protocols, the low QMCI values will be a result of the insufficient time for macroinvertebrate communities to recolonise or re-establish quickly in these high alpine sites. The Alpine-upland sites within the Ecosystem Health programme were not sampled at all in the 2000/2001 period because of the high flows experienced that season.

The majority of the other sites with low QMCI values have data sets with much higher QMCI values suggesting that the lower values are simply one-off examples most likely due to recent or unidentified local flooding events. Again these would all fall into the category of ‘natural perturbations’.

Spring fed - Plains

The lower quartile (QMCI values less than 3.8) for this category is made up of 115 observations from 36 sites. The whole data set is made up of 457 observations from 58 different sites. Of the sites contributing to the lower quartile, eight stand out as being particularly poor. All eight sites are located on the eastern margin of the plains in areas of very intensive agriculture. They have all largely been subject to channel alteration at some point in the past, most likely for land drainage purposes, and some people may consider them drains rather that spring fed streams. The main factors limiting the quality and health of these sites are;

- high sediment loads,
- little or no riparian margin to provide shade or woody debris,
- frequent stock access,
- prolonged low flows, contribute to by excessive ground water abstractions,
- surface run off with high sediment and nutrient content,
- few and infrequent flushing flows (due to spring fed nature),
- abundant macrophyte growths.

These rivers comprises most of the sites that have responded well to “Living Streams” type interventions and with concerted community involvement have the potential to increase to QMCI objective levels within a few years.

Q2. We also seek comment on the extent to which management could improve these streams, and how this might be achieved.

The discussion above describes the excursions from the target condition or upper quartiles, and shows that for different river types the excursions can be due to natural perturbations (NP) (largely dominant in upland river types) or anthropogenic causes (largely dominant in lowland types). Standard sampling protocols (not sampling in close proximity to flood events, etc.) generally limit the effect of the former (NP) excursions on data collected, so most non-compliance with objectives largely results from anthropogenic degradation.

Target objectives can be, and are, routinely achieved in most stream types, and for those suffering degradation, there are many cases (particularly “Living Streams” cases) where improved management does readily lead to acceptable outcomes. Measurable objectives in a plan thereby serve a very useful purpose of making such issues monitorable and provide more explicit requirements to address water quality and ecosystem health degradation.

More consistent application of the well established principles and practices established in the Riparian Management Classification Strategy (developed by NIWA for the ECan planning section (NIWA 2009)), the Living Streams and ICM (Integrated Catchment Management) methodologies developed by the ECan Resource Care section would be the most comprehensive mechanisms to largely achieve compliance with such objectives. Furthermore, national initiatives, such as the Clean Streams Accord, other tools arising from Ministry for the Environment strategies, guidelines and discussion papers, and Envirolink Tools processes (currently dealing with restoration methods, sedimentation, lake processes, habitat protocols and periphyton methods, plus many others) will all increasingly demonstrate the achievable methods for maintaining or improving waterways and achieving (hopefully common) national and regional objectives or targets.

You have indicated that you favour a target *range* rather than a single objective *value*. A target range can be an appropriate tool provided there is clear guidance on how such a range should be used. Without very clear guidance, the lower bound of the range can easily become a default target allowing further degrees of degradation than envisaged, or an approach of degradation of higher quality habitats to a lowest common denominator. We suggested a single value threshold measure because of its simplicity and ease of understanding. Target ranges generally provide a greater degree of complexity, poorer understanding, and are likely to lead to challenges or arguments over how they should be used by plan users.

During the hearings you particularly questioned:

Two of the outcomes in Objective WQL1 seem to be practically unachievable:

- ***Christchurch urban streams attaining a QMCI score of 4. What changes would be necessary in the biota to meet such a target? And also given that these streams are for all intents and purposes largely soft bottomed, is the recommended use of the hard bottom QMCI appropriate for these watercourses? What would be the consequences of doing so?***

The soft bottomed MCI (SBMCI) methodology was developed for use in streams that are naturally soft bottomed, for example in mudstone or sandstone country (such as in Auckland and south-west Waikato), and which generally do not occur in Canterbury. The use of SBMCI creates an expectation that rivers with a silted habitat and generally pollution/poor habitat tolerant range of invertebrate taxa, are a ‘normal’ or ‘typical’ river system.

Most Christchurch streams have a ‘gravel’ bed, which in some reaches is overlain by fine sediment. These are best described as 'silted up hard sedimentary streams' rather than naturally 'soft sedimentary streams'. Use of standard MCI tools clearly illustrates the effect of degradation resulting from such siltation, while use of SBMCI implicitly accepts the siltation as ‘natural’ and sets in place an expectation that silting of gravel bed streams is acceptable. Furthermore, if SBMCI was adopted, a dilemma then arises as to where a break-point should be positioned on those streams where a change from MCI to SBMCI objectives should occur. The River Environment Classification, developed by NIWA, would not help with providing such a break-point as it classifies all plains streams as being of parent alluvial gravel nature.

Over the past 10 years, monitoring has shown a general increase in suspended solids concentrations in Christchurch streams. This is consistent with observations by McMurtrie and Taylor (2003), who have noted fine sediment accumulation in the Avon River as one of the key factors in the decline in sensitive macro-invertebrate taxa over the past 20 years. In particular, mayfly larvae that were once abundant at many sites in the Avon River up to the 1980s are now largely absent, with siltation of the gravel stream beds being one of the contributing factors to their decline. Similarly, Taylor (2003) noted a decline in the number of trout redds (trout egg nests) and suitable clean gravel substrate as a result of siltation of areas that were previously used for spawning in the upper Heathcote River.

These observations illustrate two things: firstly that Christchurch urban streams were gravel bed rivers that, despite an urban setting, for many years supported a moderately healthy aquatic ecosystem, and that excessive amounts of fine sediment entering these waterways over the past couple of decades have had a detrimental impact on these ecosystems.

While not specifically reported, it is reasonable to assume that the presence of mayflies in the Avon River in the 1980s would have resulted in QMCI values well in excess of 4.

Similarly, if high numbers of trout were able to successfully spawn in reaches of the Heathcote River, we would expect QMCI values in those reaches to exceed 4. Indeed, monitoring by Kingett Mitchell (2005) of the upper reaches of the Heathcote and Halswell rivers in recent years (2003/04) found QMCI values in the range of 4-5 at several monitoring sites. Therefore, despite the current poor condition of invertebrate community composition at many sites in Christchurch urban streams, we do not consider a QMCI objective of 4 to be unrealistic or unachievable. Furthermore, a QMCI objective lower than 4 could be interpreted as sanctioning significant sustained degradation of the aquatic environment.

Notable exceptions are the tidal reaches of both the Avon and Heathcote rivers, which extend for several kilometres upstream of the Avon-Heathcote Estuary/Ihutai. These reaches have probably always had soft sediment substrate, although the past 150 years of urban development will have increased the extent and rate of fine sediment deposition. It is not recommended that the water quality objectives apply to the tidally influenced reaches of rivers, where low and reversed flows result in them being areas where natural processes result in the deposition of fine sediment.

2. Microbial Contaminants

In response to discussion of microbial water quality you have commented:

The officers have proposed that both the spring fed plains and spring fed urban streams should meet the "fair" category for MAC. However Table 6.3 tells us that 45 out of 47 sites in the former category, and 16 out of 17 in the latter do not meet this target now. What we do not know however is the degree to which they do not meet this target.

Q3. Can we please have some further information on the extent of non-compliance with this target in these two stream types? This could be helpfully expressed as the percentages with E coli medians of greater than 1,100 and 5,500 per 100ml respectively.

Table 6.3 (pg 101) and Figure 6-3 (pg 102) of the technical report present *E. coli* results from ECan's regional rivers monitoring programme. These data are collected quarterly, and for most of the sites presented in this analysis, the data set was limited to 20 or less data points. The national microbiological water quality guidelines are intended for use with weekly data collected during the bathing season. At least five years of data or 100 data points are required to calculate a robust Microbiological Assessment Category (MAC; MfE/MoH 2003).

Indicator bacteria concentrations are inherently highly variable, as is demonstrated by the broad distributions of data for individual sites shown in Figure 6-3. Frequent monitoring is therefore necessary to provide relevant information to the public of the health risks associated with water contact at a site. As is stated in the technical report, it is therefore important to note that use of data from the regional rivers monitoring programme provides an *indication* only of the *potential* for the different river types to comply with the contact recreation guidelines.

We note that your comment incorrectly refers to the MAC when describing the "Fair" grade objective, which indicates potential confusion with the derivation of these aspects of the grading system. To clarify:

- The MAC is calculated using historical data (last three to five years) for indicator bacteria (*E. coli* in the case of fresh waters). The categories are based on the 95th percentile of these data and are labelled from "A" through to "D".
- The "Fair" grade refers to the Suitability for Recreation Grade (SFRG), which is derived from both the MAC and the Sanitary Inspection Category (SIC). The SIC

involves assessing the potential sources of faecal contamination that may affect the site in question. To achieve an SFRG of "Fair" the MAC must be "C" or better (95th percentile less than 550 *E. coli*/100 mL) and the SIC must be "Moderate" or better.

Table 1 (below) provides the information requested by the Panel. As the guidelines are based on the 95th percentile we have included information on the percentage of sites that exceed each of the criteria (twice and ten times the 550 *E. coli*/100 mL level, respectively) using the 95th percentile of the data also. An important point to note is that depending on the laboratory practices used, the reporting of microbiological data often includes an upper detection limit (e.g. >2400 *E. coli*/100 mL). When analysing data with results reported as greater than the detection limit it is typical practice to convert these data to a value equal to the upper detection limit.

Table 1 **Percentage of sites on Spring-fed Plains and Spring-fed Plains urban rivers with median and 95th percentile *E. coli* concentrations exceeding 1100 and 5500 *E. coli*/100 mL**

	% of sites > 1100 *E. coli*/100 mL (no. of sites in brackets)	% of sites > 5500 *E. coli*/100 mL (no. of sites in brackets)
Spring-fed Plains (47 sites)		
median	4.3 (2)	0
95th percentile	74.5 (35)	12.8 (6)
Spring-fed Plains - urban (17 sites)		
median	5.9 (1)	0
95th percentile	82.4 (14)	23.5 (4)

You have sought information regarding how the proposed microbiological objective could be met for urban streams in Christchurch.

Q4. How could this possibly be achieved at even a significant number of the approximately 400 stormwater discharge points, and what might it cost at each site.

Q5. To what extent could it be effective in reducing coliform counts to the proposed target levels?

The faecal contamination issue evident in our urban streams is a result of a complex combination of sources and conditions. It is useful to consider this issue in the context of the discussions provided in the introduction to this memo regarding natural perturbations, management tools, knowledge development and timeframes.

As mentioned in your memorandum, the primary source of contamination in low flow conditions has long been considered to be the large populations of wildfowl that frequent the rivers and their banks. At higher flows other point-sources, mainly stormwater, and non-point sources are believed to contribute more microbial contaminants. The results of a recent faecal source tracking study in the Avon River (Moriarty and Gilpin 2009) support these views. Although the study was limited in scope, the results showed that at low flows the various markers indicating avian sources of faecal material were prevalent. Samples taken during higher flows in the river indicated that dog faecal markers were dominant following rainfall. There were no incidences of wet weather overflows into the Avon River from the sewerage system during the high flows sampled for this study and therefore human markers were largely absent.

It is our opinion that the non-avian sources of faecal contamination to the urban rivers, primarily through discharges from the stormwater and wastewater systems but also from diffuse run-off from the river banks, are anthropogenic in nature and therefore can be controlled by appropriate management techniques. You pointed out that treatment of microbial contaminants in stormwater is difficult and expensive and we agree with this. Nonetheless, there are numerous ways of managing these contaminants at their source that should be considered, including:

- Measures to encourage (or even enforce) dog owners to pick up dog faeces;
- Investigation of cross-connections between the stormwater and sewerage reticulation systems;
- More widespread implementation of low-impact filtering devices (e.g. swales) at the beginning of the treatment train to remove the contaminants at source;
- Street sweeping and sump cleaning;
- Planting of riparian margins to filter stormwater runoff that enters the rivers directly.

Avian sources of faecal contamination are generally considered to be natural sources that cannot be controlled, i.e. they fall into the category of ‘natural perturbations’. There are some potential management tools that could be employed to minimise contamination from this source on a localised scale however, including:

- Planting of riparian margins to discourage ducks from gathering on river banks in large numbers and creating concentrated loads of faecal matter;
- Use of bird repellent products that may be suitable for localised application in areas of high recreational use, e.g. Kerrs Reach and Antigua Boat Shed access platforms. Use of such products would need to be further investigated.

The cost of the above measures for avian and non-avian source management and their effectiveness at reducing microbial concentrations to meet the proposed objectives is difficult to estimate and beyond our expertise.

As a result of investigations, such as the Moriarty and Gilpin (2009) study described above, our understanding of this issue is increasing over time and this knowledge will assist with directing resources (both within and outside of ECan) to achieve the most effective outcomes. An important factor is the degree to which different non-human sources of faecal contamination pose a health risk to humans. Recent studies have shown that bird faeces (Canada geese, gulls, ducks, black swans) do contain *Campylobacter* (McBride *et al*. (2002) and recent ESR work cited in Moriarty & Gilpin (2009)), however there is less known about the health risk associated with faeces from other animals in the urban environment. The linkage between faecal indicator bacteria and pathogens under different conditions and from different sources is an area that requires considerably more work.

When considering the achievability of the proposed microbiological objective for urban rivers it is important to bear in mind the desires of the community and the values for which urban rivers are to be managed. The large number of submissions in opposition to the consent application for continuing wet weather discharges from the sewerage system indicates that the community generally considers the discharge of human faecal matter to our river systems to be unacceptable. Bird faeces, as a natural source, may be considered more acceptable in the rivers, while other animal sources through point and non-point discharge of stormwater are likely to fall somewhere in between. It is unlikely that this hierarchy of “acceptability” of faecal sources (natural vs anthropogenic) is directly correlated to health risk.

Despite increasingly widespread knowledge of the state of microbial water quality in urban rivers in Christchurch there is a high level of interest among the community in recreational activities, such as kayaking, rowing and punting, on these rivers. Finding a balance between community desire for improvement to ensure that recreational activities can be undertaken with lower risk to public health and the financial cost of achieving such improvements remains a difficult management issue. Defining and achieving that balance will require coordination between ECan, the Christchurch City Council and Community and Public Health as well as significant consultation and engagement with the community. The microbiological objective for urban rivers is therefore an example of an NRRP water quality objective that we anticipate will require time beyond the lifetime of the current plan to achieve.

3. Toxic Algae

In response to discussion of toxic algae blooms you have commented:

We note that blooms of species such as cyanobacteria occur now in lakes such as Forsyth and Ellesmere, and species such as *Phormidium* occur periodically during summer low flows in rivers such as the Selwyn and Ashley.

One of the principles we have decided is that the outcomes sought should be able to be reasonably influenced by the management tools available to ECan. We do not know what these are in the case of these toxic algae.

Q6. Can it please be explained to us what can practically be done to meet this outcome, and the extent to which any such measures could possibly be successful in eliminating such toxic outbreaks?

The incidence of toxic algae (both planktonic and benthic mats) has increased considerably in recent years, particularly in the eastern areas of New Zealand prone to droughts and low flows/water levels resulting from increased resource use. This has resulted in considerable research into the prediction of the onset and subsequent warning of such incidences throughout New Zealand. This work has culminated in a major draft guideline document (MfE and MoH 2009) titled "New Zealand Guidelines for Cyanobacteria in Recreational Waters". ECan staff have been involved in case studies and derivation of these guidelines on the basis of knowledge gained in Canterbury as well as from other regions of New Zealand. The guideline is intended to assist regional councils by providing a tool for monitoring and setting out a common approach for assessing potential and actual risks.

Conversely, such research and guidelines can also be used to assist management to *avoid* such conditions if they result largely from excessive use of water resources or contaminant discharges. As the incidence of such toxic growths has increased and the effects generate widespread public concern (dog deaths etc.), there is a clear expectation that regional plans, such as the NRRP, address the issue of toxic cyanobacteria blooms, or at least do not remain silent on it. It is therefore appropriate that plans give a clear mandate to require the avoidance, wherever possible, of the generation of such conditions and therefore the effects.

We have been involved in remedial situations, such as the Kaiapoi lakes where regular seasonal toxic cyanobacterial blooms have been prevented by identifying the cause (seasonal turnover of eutrophic stratified anoxic waters), and instituting cheap and simple community treatment technologies (brief periods of low volume aeration). Similar resolution of regular seasonal water quality degradation (and toxic blooms) has been achieved at a larger scale at Lake Opuha, and this has allowed the scheme to continue to be heralded as a regional success without being maligned by ongoing major water quality problems.

Toxic blooms of mat forming algae are also increasing, but there is a concomitant increasing knowledge of causative factors and mitigation steps required to manage the problem. Practical solutions may require the management of flows (NRRP Chapter 5) and contaminant/nutrient loads (this chapter and other projects), but they will remain unaddressed unless they are given a clear mandate to be addressed and for work programmes through the plan objectives.

Clear objectives in the NRRP will continue to be very important in requiring timely and focussed resolution of such issues. We expect such initiatives to increasingly assist the successful remediation of natural systems, such as lowland and alpine rivers and lakes Ellesmere and Forsyth, over time. As discussed earlier, this will not be achieved immediately, and will require progress to be made over the duration of the plan (and possibly beyond), but the issues remain important and will become increasingly the focus of public expectations if trends continue. The earlier analogies with the NRRP approach to air quality targets are equally applicable to this issue.

4. Temperature

In response to discussion of water temperature you have commented:

While we agree that a maximum temperature of 19 degrees is very desirable in rivers, streams and lakes, we cannot envisage what management tools are available to ECan to meet such a target, particularly in lowland reaches of hill fed rivers.

> **Q7. What practical steps, if any, do the officers suggest to meet these targets? To what extent might they have any substantial effect?**

Our answer to this issue lies largely in the introductory discussion of "natural perturbations" versus "anthropogenic influences". In the technical report, we comment that many values for which Canterbury waters are particularly valued (biodiversity, salmonid fisheries), are near the limit of temperature preferences or limits for their continued ability to thrive and remain productive. We acknowledge (as with most water quality data sets) that our suggested objective limits will be occasionally exceeded. These exceedances are largely the result of "natural perturbations" (periods of low flow in summer) to which populations, such as salmonids, attain a degree of resilience for short periods. However, increasing the incidence or duration of these exceedances can lead to such populations failing to thrive, or reaching tipping points where catastrophic failure of populations occurs.

Increasingly, it is becoming obvious that environmental flows are affecting peak river temperatures, and these necessitate some recognition of the importance of managing temperature regimes in rivers. This issue is well acknowledged in such strategies as the proposed National Environmental Standard on Ecological Flows (MfE 2008).

Conversely, Canterbury has been fortunate that to date there has not been the widespread development of industries with a requirement to dispose of vast quantities of waste heat (thermal electricity generation, heat intensive industries requiring steam condensation etc.). It is, however not inconceivable that such major industries may establish in Canterbury, and it is therefore important that planning objectives give clear guidance on the thermal limitations of our natural water bodies for anthropogenic additions of heat.

Practical steps are therefore not aimed to "reduce natural exceedances of the objective" as you indicate, but to prevent deliberate and/or sustained increases in the incidence of such temperature extremes as a result of human activity.

5. Dissolved Oxygen

In response to discussion of dissolved oxygen concentration you have commented:

We are not aware of the extent to which Canterbury lakes currently stratify.

Q8. Can we have some brief information on this please, where and when it occurs, and the extent to which oxygen depletion occurs in the deep, non circulating water.

We struggle to see what practical measures ECan can take or influence to increase dissolved oxygen levels in deep stratified natural lakes. While pumping oxygen into such waters has been undertaken in places, it seems an expensive remedy to what might be a largely natural problem, particularly given the excellent current trophic condition of many high country lakes.

Q9. Can the officers comment on this please?

Limnologists' understanding of the stratification of New Zealand lakes is based on the Davies-Colley (1988) publication on "Mixing depths in New Zealand Lakes". This paper describes the main features that lead to natural thermal stratification. Thermal stratification was not considered to be particularly prevalent in Canterbury lakes at that time, because of the extent of natural wind induced fetches. Furthermore, it was thought that even those lakes that do stratify, do not necessarily exhibit significant deoxygenation unless there is a strong corresponding source of high oxygen demand.

The best information on stratification of Canterbury lakes arises from the NWASCA publication "Inventory of New Zealand Lakes Part 11: South Island" (1986) and more recently Burns and Rutherford (1998) "Results of monitoring New Zealand Lakes 1992-1996". The latter publication states that few Canterbury lakes are considered "Stratified" lakes (monomictic) and any stratification is temporary and short lived.

The most detailed study of stratification in a Canterbury lake has been of Lake Alexandrina, which exhibited irregular but frequent stratification and deoxygenation. The extent of deoxygenation was questionable, but was considered to result from the eutrophication of the lake and resulting high oxygen demand in the bottom waters (generated by a mixture of settlement of algal bloom material, intrusion of sewage effluent from bach communities, and influent sediment and organic material from streams degraded by livestock access). The stratification, deoxygenation and subsequent seasonal turnover also led to notable seasonal algal blooms as concentrated hypolimnetic nutrients suddenly became available to surface waters. These subsequent blooms included both highly coloured non-toxic taxa blooms, and toxic cyanobacteria blooms. Both types of bloom are a typical consequence of such a situation. Much of this influent contamination has now been addressed through stream protection works and a requirement for bach owners to store and remove sewage effluent from the catchment. As a result, the trophic state of Lake Alexandrina is now much lower than historically recorded levels and stratification events (or the effects of them) are now seldom recorded, if at all. Lake Alexandrina is a useful example of why regional plans and their objectives should be cognisant of the potential development of such issues and should aim to prevent such situations from occurring rather than trying to remedy them.

The examples of the Kaiapoi lakes and Lake Opuha, that were described earlier in the discussion of toxic algae, are also reminders of the increasing prevalence of these conditions if they are not identified and avoided, or explicitly managed (or required to be managed).

Recent (2008/09) monitoring and modelling undertaken by NIWA, on behalf of ECan, of the large Mackenzie hydroelectric lakes shows that they routinely stratify in the summer, but do not become appreciably depleted in oxygen (only decreasing from close to saturation to approximately 80%). The models show that hypolimnetic oxygen depletion only significantly develops in these large lakes, such as Lake Benmore, when they become appreciably enriched. Such oxygen depletion results primarily from either: algal blooms providing algal material to settle and decompose in the lake bottom waters; cool influent discharges containing oxygen depleting contaminants preferentially flowing into the hypolimnion; or oxygen depleting sediment contamination settling on the lake bed.

Recent NIWA research in Lake Benmore (G. Hughes, Central South Island Fish and Game, pers comm.) has also found that both brown trout and sockeye salmon appear to seasonally congregate in deep (30m+) hypolimnetic waters prior to commencing spawning migrations. Salmonid populations in other deep lakes such as Lake Taupo, exhibit similar behaviour, and in Lake Taupo fishing activity is targeted to those deeper depths. The reason for such behaviour is unknown, but it is only possible while such hypolimnetic waters remain high in oxygen concentration and exhibit little oxygen depletion. This is one further reason why it is appropriate to set hypolimnetic dissolved oxygen targets for lakes, and to maintain awareness of their state and values (such as salmonid habitats).

It is also well known that solubility of metals such as manganese increase in the range 0f 60-70% of oxygen saturation, and bound phosphorus becomes soluble in association with these metals at this concentration. Therefore targets of aiming to limit hypolimnetic deoxygenation above a threshold of 60-70% saturation is appropriately targeting both water quality issues, and high value ecological habitat use issues.

Therefore, the purpose of the plan objectives pertaining to oxygen concentrations in hypolimnetic waters is not to *"increase the oxygen content of such waters"*, but to prevent or *avoid the depletion of oxygen in them in the first place (as a result of anthropogenic activities)*. Therefore in conclusion, while stratification of most Canterbury lakes is not believed to be a common or routine occurrence, there is potential for many of our lakes to become so affected if allowed to become enriched or receive significant discharges of either thermal or organic contaminants.

With regard to rivers, particularly in the lowland spring fed and lower hill fed streams dissolved oxygen levels during daylight hours fall far below the suggested 90% saturation target at many sites.

Q10. What are these sites please?

The spring fed - plains stream sites with low DO values are largely situated at the lower end of sluggish spring fed streams with high macrophyte biomass. The low values result from early morning sampling (beginning of water quality runs ~9-10 am) that reflects significant respiration by plants overnight. Sites that frequently exhibit this effect include the Styx River and Kaputone Stream, Taranaki Creek and Little Ashley Stream, the LII River, Sir Charles Creek, Buchanans Creek and Whitneys Creek. These rivers are generally in highly developed catchments with high nutrient concentrations and poor riparian buffer development. They correspondingly develop high in stream macrophyte biomass.

The Hill fed - lower sites with low DO values include sites in catchments such as the Waihao, Pareora, Opihi and Ashburton rivers. The results are largely from sites where flows were becoming very low or approaching drying up, and benthic algal blooms (mats and filamentous algae) were proliferating. Again these are situations that should be being avoided by setting appropriate flow regime rules (in NRRP Chapter 5) and/or management of water quality (particularly nutrient enrichment).

We observe that these low oxygen concentrations are likely due, at least in part, to a lack of turbulent water in these rivers and streams. We are not aware of what practical measures ECan can take to overcome this.

Q11. In light of this can the officers please comment on this matter at the sites where poor compliance with the proposed outcome already exists?

Our answer to this question requires consideration of whether the effects result from natural perturbations (climatic (drought) conditions), or are induced by anthropogenic effects and poor management. As stated earlier, the effects related to human activities that result in deoxygenation of rivers should be avoided wherever possible. The intent of the objective is to ensure that activities are not likely to generate or increase the incidence of such low dissolved oxygen effects, as well as subsequent effects on other objectives (such as QMCI) and values.

Dissolved oxygen concentrations can be improved where streams are suffering from degradation. There are many cases (such as "Living Streams" projects) where improved management readily leads to acceptable dissolved oxygen objective outcomes (e.g. Harts Creek and Lyell Creek). Therefore, as stated for QMCI objectives, plan objectives serve a very useful purpose of making such issues monitorable and provide an explicit requirement to address such degradation.

More consistent application of the well established principles and practices established in the Riparian Classification system (NIWA 2009; developed by NIWA for the ECan planning section), as well as the Living Streams and Integrated Catchment Management methodologies developed by the ECan Resource Care section, would assist achievement of compliance with such objectives. Furthermore national initiatives such as the Clean Streams Accord, other tools arising from MfE strategies, guidelines and discussion papers, and Envirolink Tools processes (currently dealing with restoration methods, sedimentation, lake processes, habitat protocols, periphyton methods, and many others) will all increasingly demonstrate achievable methods for maintaining or improving waterways and achieving (hopefully common) national and regional objectives or targets.

6. Clarity

We have found the existing data on clarity hard to interpret because it is spatially limited, whereas there is far more data on turbidity.

Q12. Given that the outcome proposed is of clarity, can we have some explanation of the relationship between clarity and turbidity in different types of river in Canterbury.

As is noted in Section 4.5 of the technical report, Environment Canterbury's regional rivers monitoring programme does not currently include visual clarity and there is no concurrent data set for turbidity and clarity that covers the full range of river management units in the region.

The NIWA National Rivers Water Quality Network (NRWQN) data set for 10 sites in Canterbury does include both clarity (measured using the black disk method) and turbidity. A plot of all these data from 1989 to 2007 is shown in Figure 2 using log scales. The plot and trendline show that there is a roughly inverse relationship between these clarity and turbidity data, although there is a wide amount of scatter about the line. The scatter indicates that prediction of one set of data from the other (e.g. converting turbidity data to clarity data based on the equation shown) would not provide accurate results.

Figure 3 displays the same data broken down into individual sites and shows that the nature of the relationship between clarity and turbidity differs between sites. For each individual site, the data remain scattered about the trendline, although the fit of the data to each trendline is better for some sites than others. Similarly, an analysis using data collected at baseflows on 96 rivers throughout New Zealand concluded that clarity can only be estimated roughly from turbidity in individual rivers because of the high standard error in the relationships (Davies-Colley and Close 1990).

The NRWQN data for Canterbury is restricted to 10 sites on rivers of Alpine, Lake-fed and Hill river types. Relationships between clarity and turbidity vary among these rivers due to differences in the optical character of suspended matter, and this variation is likely to be even greater when considering Spring-fed and Banks Peninsula river types. Particle size, shape and composition are the most important characteristics of suspended particles that influence their optical character (Davies-Colley and Smith 2001). Factors such as inorganic versus organic content and clay versus quartz mineralogy strongly influence light attenuation in water and therefore perceived visual clarity.

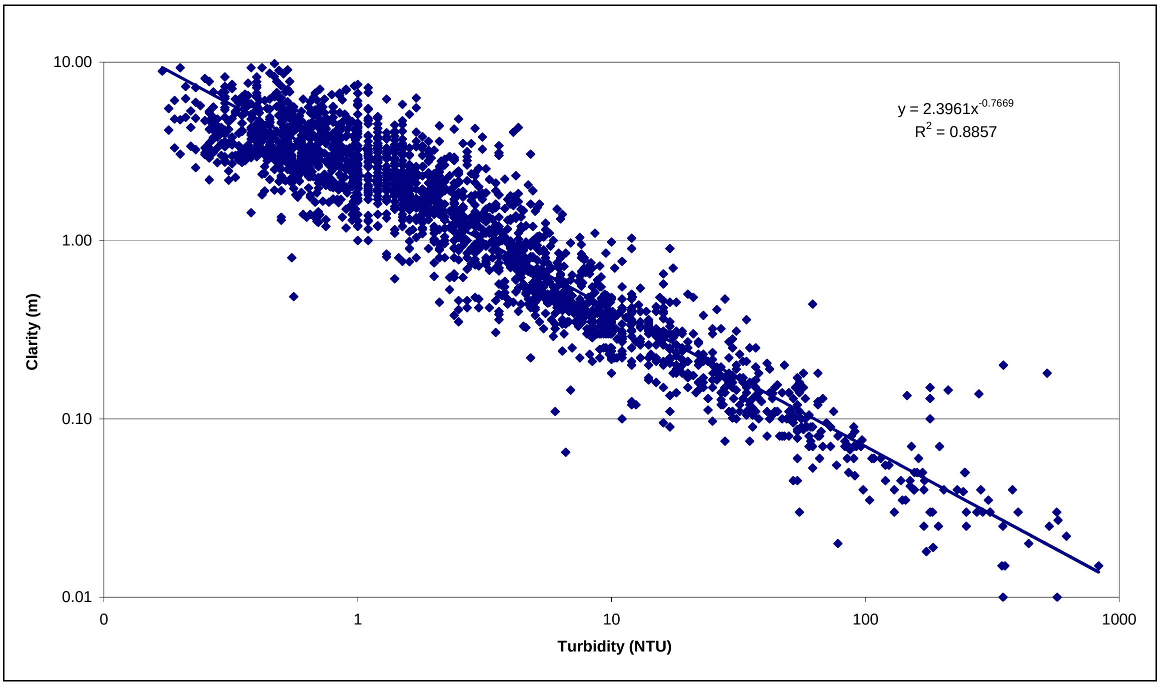

Figure 2 **Relationship between clarity and turbidity for all 10 sites in Canterbury included in the NRWQN programme (data from January 1989 to May 2007). Trendline is a power relationship with equation and R^2 value shown.**

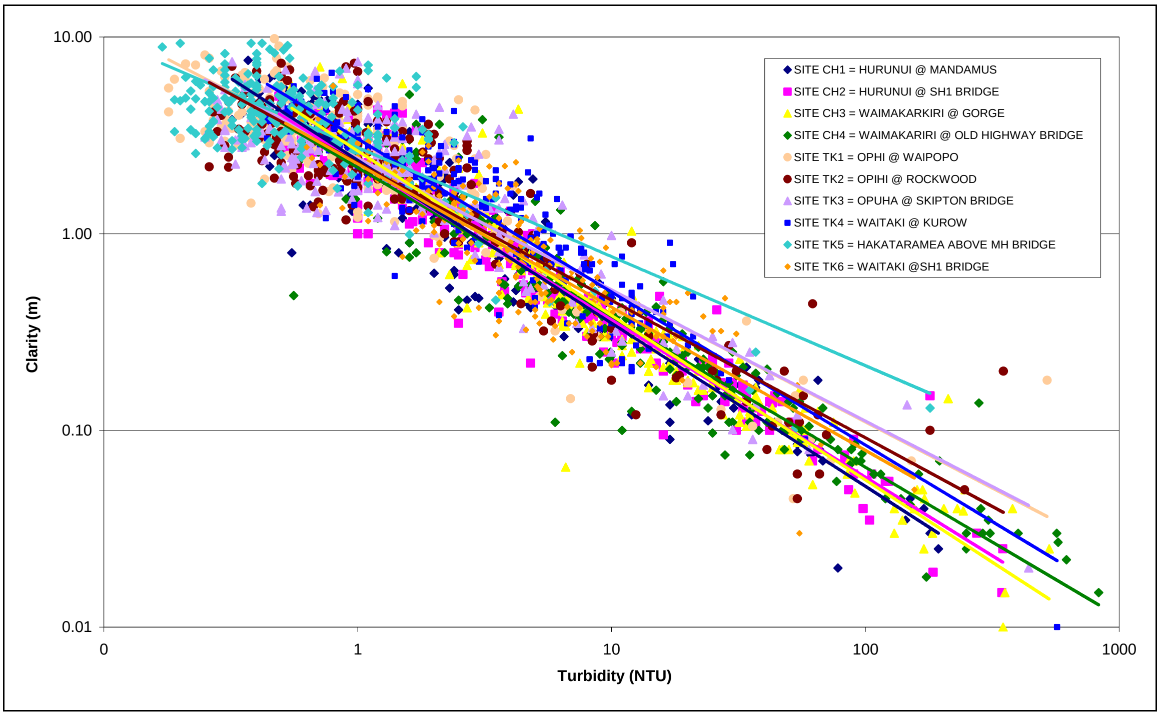

Figure 3 **Relationships between clarity and turbidity at the 10 individual sites sampled in Canterbury in the NRWQN programme (data from January 1989 to May 2007). Regression lines are power laws.**

Turbidity measures the side scattering of light using a nephelometer and calibration using standards. Results can differ between turbidity meters and using different standards. Turbidity is considered to be *indirectly* relevant when assessing environmental problems because the measurement is relative to arbitrary standards (Davies-Colley and Smith 2001). By contrast, visual clarity measures the sighting range of a black disk viewed horizontally through water. Davies-Colley and Smith (2001) consider that visual clarity is more environmentally relevant than turbidity because it is a *direct* measure of an optical attribute of water that strongly affects aquatic habitat and human use of waters.

The lack of region-wide monitoring of visual clarity will be addressed by an upcoming review of ECan's regional river monitoring programme. Section 4.8 of the technical report describes options for gathering data to develop adequate correlations between clarity and turbidity for individual sites so that historical turbidity data sets may be used on a site-specific basis for assessing the visual clarity objective.

You have also questioned some of the targets proposed.

We also question some of the targets proposed. If we look for instance at existing median clarity data, for alpine rivers neither the Waitaki at SH1 nor the Waimakariri at either the gorge or the old highway bridge come even close to a median clarity of 1.6m at less than median flows. Further, for reasons that are certainly not clear to us, both rivers get less clear further downstream.

Q13. What might be the reasons for this?

Q14. What practical steps could be taken to improve the median clarity of the Waimakariri at the gorge given the extensive nature of upstream land use, and the large area of the catchment that is in DoC tenure?

Q15. Similarly, what practical steps could be taken to limit the reduction in clarity that occurs in the Waitaki and Waimakariri Rivers in the reaches upstream of SH1?

Q16. The same issues arise in relation to hill fed rivers, where there is some evidence of declining clarity downstream. What comment do officers have on this please?

The question of declining clarity in braided rivers with increasing distance downstream was partially addressed by John Hayes in his evidence prepared for the Central Plains Water Scheme hearing (Hayes 2008). Hayes analysed the NRWQN data for the two Waimakariri River sites and found that at flows greater than about 40 m^3/s, when water clarity is in the range 1-2 metres at the Gorge, clarity reduces downstream to the Old SH1 Bridge and that the difference in clarity increases with increasing flow. He stated that re-suspension of fine sediment is likely to be the main reason why the water gets dirtier downstream with increasing flow. At lower flows the ability of the river to re-suspend fine sediment is reduced. Similar trends can be expected on other large rivers, including the Waitaki and Hurunui rivers.

There are multiple potential sources of the fine sediment that is deposited in the middle reaches of these rivers and re-suspended when flows increase. These include:

- Natural inputs of sediment from erosion processes in the mountains and high country;
- Gravel extraction activities, mostly in lower reaches, which are likely to play a significant role in releasing fine sediment to the Waimakariri River in particular;
- Inputs of sediment from tributary streams and rivers, related to intensive agricultural activities on the plains;
- By-wash discharges from irrigation schemes.

The first of these is from a natural source and is an important part of the sediment transport that takes place between land and coast. We certainly do not intend that such processes should be controlled to limit effects on water clarity. The remaining sources listed are anthropogenic and management of activities to reduce sediment inputs from these sources is possible. On some rivers where nutrient enrichment is a particular issue, such as the Hurunui River, it is likely that particulate algal matter also contributes to reduced clarity at times.

It is the anthropogenic sources of sediment, as well as nutrients that contribute to undesirable levels of algal growth, which need to be the focus of management to reduce impacts on visual clarity. Management tools include improvement of gravel extraction practices to reduce fine sediment disturbance and discharge, increased uptake of best practice farm management practices to reduce sediment and nutrient inputs to streams, and reduction of point source discharges such as irrigation bywash and discharge of gravel wash water.

We agree that the targets will not always be met, but the rivers are highly valued for contact recreation and so the appropriate national guideline targets should be strived for. Again, the objective is to ensure that appropriate contact recreation targets are achieved as often as possible, and are not compromised by anthropogenic activities.

The proposed visual clarity objective accounts for some of the effect of flows on clarity by only considering clarity measurement taken when the river is at less than median flow. For large rivers in particular, the reduced data set will still include some elevated flows that are experienced during the recession phase of floods and freshes. As an example, our analysis of the NRWQN data set determined that the median flow at the Waimakariri Gorge site was 79 m^3/s (using flows on the dates of water quality sampling only) and Hayes (2008) showed that clarity decreases downstream were apparent at flows greater than 40 m^3/s, i.e. well below our calculated median. These flow recessions are natural perturbations, as are the sediment inputs from natural erosion processes occurring in the mountains and high country. When utilising the results of state of environment monitoring to assess whether the water quality objectives are being achieved it will be important to take into account these natural perturbations, particularly for the alpine rivers that are so dynamic in nature. More detailed analysis of flow and clarity conditions will be required for these rivers to ensure that the data used is representative of those times when high clarity can be naturally expected.

As an example, you note that the median clarity data for the Waimakariri Gorge site at less than median flows does not meet the proposed objective for visual clarity for Alpine rivers and you ask what practical steps could be taken to improve clarity at this site. Due to the very high and diverse uses made of the middle and lower Waimakariri River, it is important that clarity objectives prevent anthropogenic degradation of water clarity at times when high (and compliant) clarity is an important and highly valued feature of the Waimakariri River. Our analysis of the available data for the Waimakariri Gorge site indicates that the recommended visual clarity objective for Alpine rivers of 1.6 metres is met 35-40% of the time using data collected at less than median flow. Over time, as a more extensive data set of visual clarity is collected in Canterbury rivers, we will be able to better characterise the relationship between clarity and flow in different river types and therefore refine the methods used to assess compliance with the clarity objectives. The additional information gathered could also allow us to re-define the objectives if it becomes apparent that this is necessary.

High clarity is a particularly significant natural characteristic of Canterbury's spring fed streams but it is equally highly valued in the larger rivers under low flow conditions. It is important that the plan sets water clarity outcomes that reflect the values widely held by the public for water bodies and that anthropogenic contributions which cause further breaches of these are effectively dealt with at the policy and rule level. If related to non-point sources then control via other methods may be required as well.

<u>7. Sedimentation</u>

While we are pleased that this section no longer refers to "embeddedness" we still consider that the information presented does not cover the key problem, which is siltation.

Our reason for this is that Table WQL5 and the technical report refer to fine sediment of less than 2mm diameter. However particles between 0.125 and 2mm are sand, which is one of the most mobile particle categories found in nature. For this reason sand is generally desirable in rivers. We also note that sand is relatively abundant in our braided, so-called gravel-bedded rivers. Greywacke, which is the main rock supplying their sediments, breaks down into a wide range of particle sizes, including substantial amounts of sand. To treat sand in those rivers as undesirable is perverse given that it occurs naturally in quite high proportions.

In comparison to the braided rivers of the plains, streams such as those on Banks Peninsula, the downlands of South Canterbury and Christchurch urban streams contain very little sand and considerable silt. This is because the sediments are pre-sorted into finer sizes by norwest winds and are then deposited as thick loess sheets that get reworked by erosion (and earthworks for subdivisions etc.).

Particles below 0.125mm comprise silt and clay, with these being among the most immobile particles in nature and those that cause siltation. It is this that we need be concerned about.

Q17. Accordingly – and presuming that is available – we want the information in Section 4.4 of the technical report rewritten to focus only on siltation, i.e. particles less than 0.125mm. Once we have that we will look at the outcomes proposed, about which we then may have further questions.

We have considered this issue at length in the original report and following receipt of your comments and questions. Very similar issues have also been widely considered by other researchers and management agencies, particularly in the USA. There has also been considerable discussion recently in association with an Envirolink FRST-funded project on sedimentation tools for regional councils.

The primary reason for managing the deposition of fine sediment (in New Zealand and internationally) is to avoid the effects of sustained deposition of fine sediments on bed habitat. In terms of the river bed habitat values affected, deposition of fine sediment largely:

(a) fills the interstitial spaces between cobbles and gravel, destroying habitat and refugia for fish and insects;

(b) smothers surfaces on which productive biofilms and periphyton should grow;

(c) reduces intra-gravel water flows through trout and salmon redds and other native fish nests;

(d) traps organic material (leaves, woody material, etc.) in a fine sediment matrix which subsequently decomposes and reduces intra-gravel water quality (anoxia etc.);

(e) reduces potential upwelling and downwelling of waters in contact with groundwaters.

The principal issue you raise is whether the objective should encompass material <2mm (coarse sand to clay) or be limited to a finer fraction, material <0.125mm (silt and clay). We agree that there is good evidence to indicate that the settling of the finer fraction is more problematic in terms of the difference between entrainment velocity and settlement velocity. The finer fraction also has incrementally greater ecological effects on habitat and production of biota (smothering, total loss of sediment permeability/transmissivity etc.). However, the accompanying assumption, that the sand fraction is not a problem and does not have ecological or environmental effect, is not so clear cut, and is not generally supported by NZ and international ecologists. Furthermore, this was recently vigorously debated by the 'science providers' for the above mentioned ENVIROLINK project, and the unanimous view of science providers from NIWA, Landcare Research, University of Otago, and Cawthron Institute was that sand sized fractions must be included because of their similarity of "effect" when present in excessive quantities in the bed.

In the Motueka ICM study (Phillips and Basher 2005), the sedimentation monitoring methods were developed primarily to be able to measure and follow the effect of slowly or episodically moving 'sand slugs' travelling down from particular developed and/or eroding catchments through the otherwise relatively clean gravel Motueka River. New Zealand researchers (above) are particularly focused on the environmental effects of, not only silt and clay sized fractions, but also sand sized fractions affecting river bed quality. We acknowledge that 'sand' is not as implicitly a 'bad' particle fraction, but do consider that 'excessive' quantities of it are harmful to the aquatic environment, as illustrated in NZ and overseas (Australian ‘sand slug’) studies.

While settled sand particles may be cleared and re-entrained more readily than silt and clay particles, their excessive accumulation (such that they become visible as bed layers) can still be a significant environmental problem. Our experience is that fine sedimentation is widespread in many lowland streams and ‘sand deltas’ have been observed forming at times adjacent to and downstream of discharge points (particularly stormwater outlets). The subsequent dispersion of sand and silt over downstream reaches generates excessive generalised bed sedimentation, and resulting adverse effects on stream ecology.

Furthermore, changes to river processes (and particularly flow regimes) can allow changes to these transportation processes that result in, not only fine sediment accumulation, but also sand accumulation beyond that which would naturally occur under a natural flow regime. This is a potential issue where floods and fresh flows are reduced by dams or major abstraction capabilities.

An additional issue arises where irrigation schemes settle sediments from abstracted waters in settlement ponds and then sluice the primary settled sediments back to the source river in large quantities but at times of much lower natural river flows. It is debatable whether the rivers have the ‘energy’ at these times to then adequately process and transport such large quantities of sand and silt. This activity has historically been practised at the RDR on the Rangitata River and is proposed at a number of major new irrigation schemes. The material settled and proposed to be sluiced back is primarily fine through to coarse sand. We believe the NRRP should be cognisant of these proposed activities, and objectives and controls be phrased to give clear guidance on the significance, potential issues, effects, and outcomes sought.

From an objective *monitoring* perspective, any sedimentation measurement and monitoring methods (as well as objectives themselves) have to be “effective and achievable” (as you require for all proposed objectives). The Envirolink studies in New Zealand, and others overseas, have examined the methods of monitoring and quantifying fine sedimentation or siltation in river beds (and particularly considered ‘embeddedness’ methods versus ‘aerial % cover of fine sediment’ methods). Visual methods have been widely identified as simple, quick, cheap, and reproducible, even if only dealing with the consequential end result of accumulation (when the bed interstitial volume has become ‘full’). This is also the conclusion of Landcare Research scientists for the Motueka catchment, for Otago, University scientists advising Environment Southland, and Cawthron Institute scientists advising several other regional councils. Therefore, we (as with most of the international literature) favour such ‘affordable’ practical methods of quantifying visible surface accumulations of finer sediment fractions. They are within the capability of council and other parties to undertake and report at reasonable frequencies and spatial distributions.

Most importantly to consider, is your issue of whether different fine sediment fractions should be easily assessed separately. The principal difficulty we (and other colleagues associated with the Envirolink project) see with limiting a visual method to a smaller size fraction is the inability for the observer to differentiate between settled material only <0.125mm and a mixture of both silt and sand without using (relatively expensive) grain size analysis.

Our and others (Envirolink) experience, of monitoring for the past few years, is that in almost all cases the identified fine sediment matrix is a variable mixture of sands, silts and clays. Furthermore, in discussing this with field staff, the qualitative differentiation between whether a sedimentation condition was composed of sand only, or a mixture of sand and silt/clay, or silt and clay only is very difficult. The latter can be determined from sediment consistency on ‘feel’ (grittiness indicates presence of sand), but the other conditions are a continuum. Trying to visually differentiate a 'break point' in such a continuum generates considerable variability or uncertainty, and largely prevents the issue from being addressed.

Furthermore, as previously stated, the effects we are trying to manage or limit (listed (a) to (e) above) are generated largely by the deposition of fine sediment fractions that clog or smother interstitial spaces and surfaces. For this reason alone the separation of different particle size classes (while logical from a hydrodynamics perspective) is not valid from an ecological 'effects' perspective.

The objectives we propose are not 'zero' levels of fine sediment sedimentation, and recognise that there are considerable measurable or observable background levels of fine sediments in rivers. We believe this acknowledges that material such as sand is an important natural component of river bed sediments particularly in larger gravel-bed rivers. Our proposed objectives clearly indicate that it is not appropriate to be significantly increasing the content of fine material in the active bed of flowing rivers.

We also acknowledge that the issues in spring fed streams and streams on Banks Peninsula are largely ones of accumulation of silt and smaller sized particles for the reasons you state. However, for the reasons identified above, we do not consider it a flaw to leave the definition of fine sediment as broad as "up to 2mm" size particles. This is largely to give effect to the logistical problems of implementing assessment methods that would otherwise have to differentiate between sands and silts. It would also open up a line of defence, that "it isn't silt, it is sand" requiring expensive analytical demonstration. We would also contend that sand is only infrequently readily transported by meandering spring fed streams, and then only by significant flood events. Excessive accumulation of sand continues to be considered detrimental to the ecological values of all rivers, whether it is expected to be present or not.

In summary, we acknowledge the inherently different hydraulic behaviours of sand, silt and clay, and their different origins. We also acknowledge that a certain proportion of sand in rivers is natural, expected and beneficial. However, our concerns and suggestion to maintain the lack of distinction between sand and silt sized particles is on the basis of:

(a) avoiding excessive accumulation of all fine bed clogging particles;

(b) relevance to ecological 'effects' being generated by all particle sizes;

(c) the practicality of monitoring fine sediment accumulation effectively and achievably.

We continue to believe this is a significant issue that needs to be addressed, and is an area of science that has been acknowledged and is rapidly developing at present.

8. LakeSPI

You have asked:

Q18. Which Canterbury lakes presently have recorded infestations of exotic aquatic macrophytes?

Q19. What practical measures can ECan take to control or manage the further spread of exotic macrophytes in Canterbury lakes?

Furthermore we understood at the hearing you asked:

> ***Comment on the suitability of the Lake SPI scores in Table WQLAA, Objective WQL1, given that the score would be affected by the introduction of weed species, e.g Lagarosiphon sp, which has nothing to do with land use in the catchment. Lagarosiphon sp is already present in lakes such as Wanaka and Dunstan, and lakes such as Benmore, Sumner or even Coleridge could potentially be infested as a result of recreational activities rather than land use.***

The first question is best answered with reference to a recent paper published by NIWA (de Winton *et al.* 2009: *Spread and status of seven submerged pest plants in New Zealand lakes*). Inland, Lake Benmore is the only lake in Canterbury with any of the seven major plant pest species established. Current advice from NIWA is that the *Lagarosiphon* infestation identified in Lake Benmore since 2005 is stable and unlikely to significantly increase provided nutrient inputs remain limited.

Extensive monitoring programmes are funded by ECan to maintain appropriate frequencies (some annual, others up to 5 yearly) of surveillance of 'at risk' lakes (i.e.,those with high use, easy access, regular boat use etc.). In association with these surveys, a regular rolling assessment of full LakeSPI assessments in many of these lakes is also being conducted.

The biosecurity functions and consequences of further invasion and spread of pest plant species are dealt with in a number of different ways. NRRP Chapter 6 contains rules explicitly preventing the deliberate introduction or spread of such pest species, and Policy WQL1(1) (b) of Chapter 4 specifically avoids inter-catchment transfers where the discharge of water is likely to facilitate the movement of pest species between catchments.

Further, the Canterbury Pest Management Strategy identifies many of these aquatic plant pest species as priority pest species and has developed strategies for regular survey, surveillance and responses (eradication, containment etc.) should they be identified. Efforts in this regard are documented for the Lake Benmore incursions. There is also considerable liaison and cooperation with other agencies (such as Biosecurity NZ, Meridian, LINZ etc.) who are also involved in the control of plant pests. Pest plant incursions are taken very seriously and a range of practical measures are in place to prevent or avoid incursions or to respond promptly to any further spread identified. Rapid or further spread of such pest species is therefore not inevitable or assured.

LakeSPI is a broad general lake status monitoring tool and is not entirely focussed on invasive pest weed incursions. It is a relatively new lake monitoring tool developed by NIWA for monitoring the overall ecological condition or status of New Zealand lakes. It has been increasingly adopted by a number of regional councils for monitoring the health and condition of lakes for a variety of purposes, including state of environment monitoring. For example, LakeSPI is used by Environment Waikato to monitor 33 lakes (Edwards *et al.* 2005), Northland Regional Council to monitor 80 lakes (Wells and Champion 2008), and Environment Bay of Plenty to monitor 12 lakes (Clayton *et al.* 2005; Edwards and Clayton 2008), while in Canterbury it has been used by DoC for 15 lakes (de Winton 2008), and Environment Canterbury is planning to survey at least ten additional lakes annually.

The perceived issue, that the LakeSPI scores would be excessively affected by the introduction of weed species (and in particular the example of *Lagarosiphon sp.*) is a possibility, but is just one of the many functions of the LakeSPI methodology. Concern that LakeSPI indices are responsive to multiple influences (water quality, exotic weed invasion, climate effects etc.) are not unique to LakeSPI, but are a common attribute of all ecologically based objective or monitoring measures. Therefore, it is not a deficiency of the LakeSPI tool and it will respond to an array of influences including plant and animal pest introductions.

The reason for setting measurable objectives is to ensure that targets are set for overall environmental quality, they are monitored, and any changes detected are considered and responded too. Consequently, the indicator used in an objective needs to be able to identify, describe and explain such influences on resulting changes in lake condition from monitoring data. In that respect, the LakeSPI methodology is made up of two indices (a 'native' condition index, and an 'invasive' condition index), which are calculated separately, and then calculating a third (overall LakeSPI index) by combining these. The combination of three different indices describes the overall state and what features have contributed to it (state of invasiveness and health of the native flora respectively).

For regional monitoring purposes, the LakeSPI indices are calculated from both a number of widely spaced transects. Furthermore, the overall score is calculated as a percentage of the maximum possible score for each lake's characteristics rather than as a raw score (i.e. an 'expected' score discounted for attributes, such as shallow lake depths (as at some of our smaller lakes), or naturally reduced water clarity (as in the Mackenzie hydro-electric lakes)). Therefore, such LakeSPI percentage attainment indices are more useful for assessing lakes against their own maximum potential score, or of their limitated potential condition, and/or against regional targets for maintenance of values. Conversely, raw or absolute LakeSPI assessment scores are more useful for assessing absolute biodiversity value outcomes and comparing them at any scale (i.e. answering a question such as "which is the 'best' lake for plant biodiversity in NZ"?). This latter function is more aligned to Biodiversity Strategy outcomes or those of agencies such as the Department of Conservation.

Of the lakes specifically questioned by the panel during the hearing, Lake Benmore, currently has varying levels of infestation of *Lagarosiphon sp* (as do lakes Dunstan and Wanaka in the Otago region), but lakes Coleridge and Sumner do not. This will inherently result in an overall score reduction in Lake Benmore if *Lagarosiphon sp* becomes more widespread in the lake (i.e. if it occurred in all transects monitored). However, the separate indices would clearly show this effect and the spread of exotic weeds can be readily separated from other influences. Effects attributable to expansion of *Lagarosiphon* sp growth would therefore be placed into a category of "natural perturbations" or "other causes".

It is theoretically possible to 'factor out' such pest infestation effects from the LakeSPI indices (such as calculating maximum possible score with abundant *Laragosiphon* present and then scores being a percentage of that adjusted maximum). However, that would generate unique and incomparable indices for national or regional comparison. It is more valid to leave any infestation effect within the index values and explain them when reporting on the results of any surveys. It is also important to identify that the effect of such exotic invasions on lake condition can also be magnified by water quality effects and so for that reason alone should remain.

Almost all other ecological indices commonly in use respond to "other" effects such as exotic invasions (*Didymo* on periphyton guidelines; exotic fish (trout) on fish communities indices (IBI), exotic invertebrates on native invertebrate communities (QMCI)) but these do not prevent them from being used for a number of purposes including setting objectives. Firstly, they are used to determine state or trends in the condition of a water body, and then if there are trends or changes then the data are interpreted to determine whether such changes are caused by the "expected" variable (water quality deterioration) or from natural or unexpected causes. If all indices and standards were omitted on the basis of their potential to also respond to "other causes", then we would largely discard them all and have few if any useful objective measures for ecosystem health or water quality.

LakeSPI and other ecological and objective indices are now being widely adopted and implemented in regulatory and planning functions in other regional councils (see earlier references). They are also being widely used in national reporting of outcomes (MfE 2006).

It is likely they will have greater prominence in programmes in the future and will become nationally accepted as an objective measure or monitoring tool as the Ministry for the Environment moves towards common and nationally consistent monitoring and reporting methods.

Recent reassessment of LakeSPI reporting and objective categories by NIWA (Clayton pers. comm.) has reaffirmed the LakeSPI assessment and reporting categories of Hamill and Lew (2006) but recommended that an adjustment is made to the 'Excellent' category to make it more achievable (>75% rather than >85%). Beyond that, the responsiveness to effects such as invasive species can be managed by the broad philosophical conditions of "unless as a result of natural perturbations or other causes".

In summary, we acknowledge issues with the responsiveness of ecological indices, such as LakeSPI to other influences, such as invasive pest plants. However, we feel these can and will be managed in the data interpretation stage, and this hazard is greatly outweighed by the value of having an otherwise robust regional and national lake ecological condition objective and monitoring tool incorporated in Canterbury regional planning objectives.

9. Trophic Level Index

Q20. It would be helpful if for the high country lakes listed on pp 51 of the technical report if for each lake we had its approximate surface area and median volume.

This is because lake trophic status is partly a function of morphometry, and it seems that at least some of the more enriched high country lakes are those that are small and shallow and accordingly more prone to eutrophication. Examples include Georgina and the Maori Lakes, although obviously enrichment in lakes such as Clearwater has other, readily discernible causes.

A list of Canterbury lake surface areas provided by NIWA (P. Champion) is attached as an appendix to this memo. This list does not include median lake depth or median lake volume. We agree that lake size does have a bearing on *susceptibility* to eutrophication and therefore it is imperative to ensure clear measurable objectives are in place to give weight to a range of mechanisms to safeguard the high country lakes.

We also provide a graph below that schematically illustrates the issue you raise in our recent (2009) high country lake monitoring. This shows that shallower lakes exhibit greater trends of degradation, and/or are in higher eutrophication classes. Identification of such recent trends further reinforces the need for clear water quality outcomes to be incorporated into the NRRP objectives so that appropriate management responses can be identified and implemented.

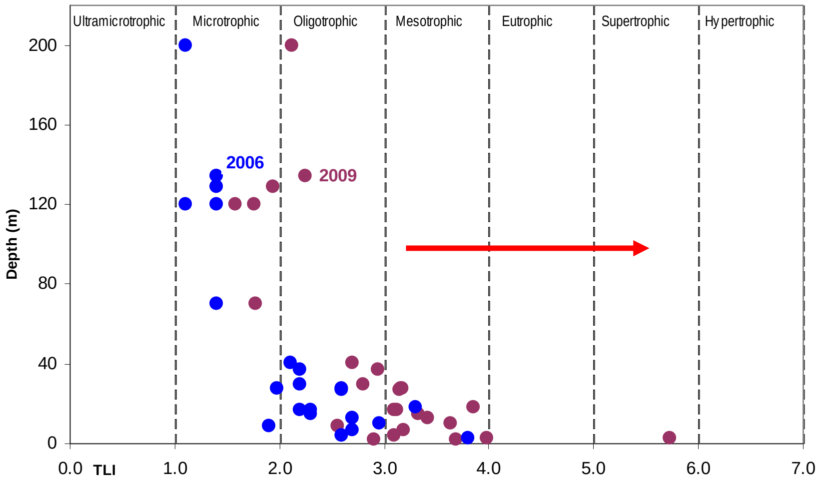

Figure 4 **Trophic level index (TLI) in 2006 and 2009 categorised by depth (m). All lakes have been degraded over the last four years, irrespective of their depth.**

You also question objectives for lowland lakes and state:

We think it is hopelessly impractical to set a target TLI of 4 for coastal lagoons. This would in most cases involve a massive 95% reduction in chlorophyll a levels, and given the vast amount of nutrients recycled via sediment, seems an impossible ask. This sets up ECan to fail, which is not something we endorse.

Examples of lakes in this category include Forsyth and Ellesmere.

Q21. Short of complete removal of all existing sediment, what practical steps could possibly be taken in these two lakes to reduce TLI to 4? Over what time period?

Another example is Lake Rotorua, which is inland of Kaikoura Airport, has an area of 43ha, and a catchment of 165ha. It has a TLI of 6.7, and so is hypertrophic. Current catchment land use is extensive grazing in part of the catchment, with some reverting scrub and wetland. According to Alastair Wright here is no history of fertiliser use. Lake turnover time is very low, by my estimate perhaps 5-10 years. The lake is a wildlife refuge, with a large resident breeding population of protected shags, along with many game birds and species such as protected crested grebe.

Q22. How could a lake like this possibly be “managed” to reduce the TLI to 4?

We had also previously identified similar questions from the hearing, as below:

> ***The TLI target of 4 for coastal lakes does not appear to be attainable given current trophic status and the volumes of nutrients that would be bound up in the sediment of the lakes. Can information be provided about the current nutrient and Chl. a levels in lakes Forsyth and Ellesmere? What proportionate reductions would have to be attained to reach a TLI of 4, and how that could possibly be achieved?***

Lake Forsyth/Te Roto O Wairewa and Lake Ellesmere/Te Waihora are highly enriched lakes, with trophic level index scores in the range of 6 -7 (hypertrophic) (Table 2). Consequently, Lake Forsyth/Te Roto O Wairewa develops a bloom of the toxin-producing cyanobacteria *Nodularia spumigena* nearly every year requiring warning notifications for about 5-6 months of each year. Nearby Lake Ellesmere/Te Waihora occasionally develops a toxic algal bloom as it did this past year and warnings about recreational use of the lake were in place for four months. Other impacts include loss of water clarity and occasional fish kills.

Wainono Lagoon has a TLI in the range of 5.5-6 (supertrophic) and Coopers Lagoon/Muriwai has a TLI of around 4 (mesotrophic/eutrophic boundary). Toxic algal blooms are not common on these lakes, although high spring and summertime phytoplankton biomass (chlorophyll a concentrations) does result in loss of water clarity and aesthetic appeal.

There is a strong desire among much of the community that use these lakes to see an improvement in their general condition. Therefore, it is appropriate that water quality objectives are set at a level that reflects the values held for these lakes and which provides a framework within which appropriate management responses can be identified.

Table 2 Range of trophic level index values for coastal lakes

Lake Management Unit	Lake	Overall average TLI	Range of annual TLI
Coastal lakes	Lake Forsyth/Te Roto O Wairewa	6.4	6.3-6.5
	Lake Ellesmere/Te Waihora	6.8	6.6-7.0
	Wainono Lagoon	5.8	5.5-6.1
	Coopers Lagoon/Muriwai	4.1	4.0-4.2
	Lake Rotorua (Kaikoura)	6.7	

Coastal lakes are more vulnerable to nutrient enrichment because they are at the lower end of catchments, and many may have been in a moderately enriched state prior to European colonisation. However, there is no doubt that modification of the landscape and in particular intensification of agricultural land use has resulted in further enrichment of these lakes.

The issue is how much of an improvement against their current condition is appropriate relative to their current and potential values and what is achievable. There is also considerable uncertainty in relating TLI thresholds to specific community outcomes and desires (i.e., what TLI is needed that ensures the lakes are suitable for recreational use, have acceptable appearance and acceptable mahinga kai values). Nonetheless, we are reasonably confident that a TLI of around 4 will protect such values.

In the case of lakes Ellesmere and Forsyth, a significant reduction in inputs and internal loads of total nitrogen and phosphorus are required. Quantification of the reduction required in one or both nutrients is still the subject of considerable further research. From simple examination of water quality data (see Table 3 below), reductions in the order of 5 and 10-fold decreases in nitrogen and phosphorus loads respectively are required for both lakes to achieve a TLI of around 4. This could only be achieved in the long term, over several decades.

As with NRRP - Chapter 3 it is not unreasonable for a plan to set long term objectives and track a trend of improvement over time. Achievement (or not) of target rates allows responsive consideration of whether further or greater interventions are required.

If the water quality objective sets a lower quality target such as TLI of 5 this makes achieving the outcome more realistic for lakes Ellesmere and Forsyth. However, this then sets a lower (degraded) target for other coastal lakes that are in better condition, e.g, Coopers

Lagoon/Muriwai. Another option is to separate the coastal lake management unit into large and small coastal lakes.

Table 3 Summary data of total nitrogen, phosphorus and chlorophyll a concentrations in 4 coastal lakes

	Minimum	25%ile	Median	75%ile	Maximum	Mesotrophic/ eutrophic boundary (TLI=4)	Eutrophic/ supertrophic boundary (TLI = 5)
Lake Ellesmere/Te Waihora							
Total nitrogen (mg/L)	0.8	1.7	**2.00**	2.2	2.8	0.34	0.73
Total Phosphorus (mg/L)	0.02	0.16	**0.20**	0.3	0.4	0.02	0.04
Chlorophyl a (ug/L)	8.5	58.5	**73.0**	96.0	208.0	5.0	12.0
Lake Forsyth/Te Roto O Wairewa							
Total nitrogen (mg/L)	0.4	0.9	**1.20**	1.9	12.0	0.34	0.73
Total Phosphorus (mg/L)	0.02	0.08	**0.14**	0.3	1.4	0.02	0.04
Chlorophyl a (ug/L)	5.0	17.9	**33.2**	81.4	60365.0	5.0	12.0
Coopers Lagoon/Muriwai							
Total nitrogen (mg/L)	0.81	1.20	**1.30**	1.60	2.30	0.34	0.73
Total Phosphorus (mg/L)	0.004	0.004	**0.01**	0.02	0.07	0.02	0.04
Chlorophyl a (ug/L)	0.20	1.10	**1.9**	3.20	48.00	5.00	12.00
Wainono Lagoon							
Total nitrogen (mg/L)	0.47	0.94	**1.25**	1.50	4.80	0.34	0.73
Total Phosphorus (mg/L)	0.04	0.10	**0.17**	0.30	4.50	0.02	0.04
Chlorophyl a (ug/L)	0.8	3.9	**9.7**	20.4	237.7	5.0	12.0

The options are summarised below:

- Splitting coastal lakes into two separate management units
    - large coastal lakes (Lake Forsyth/Te Roto O Wairewa and Lake Ellesmere/Te Waihora) - TLI objective of 5
    - small coastal lakes (all others) – TLI objective of 4
- Setting TLI of 5 for all Coastal lakes (and risk degradation of some lakes)
- Setting TLI of 5 for all Coastal lakes plus adding a statement requiring the maintenance of lakes that are in better condition (TLI less than 5)
- Setting a TLI of 4 for Coastal lakes acknowledging a long-term timeframe for some lakes – and including an objective of trend of improving condition for lakes severely degraded.

The situation of Lake Rotorua in Kaikoura is an unusual one and of interest to other agencies as well as ECan. A monitoring programme and report documenting the state of the lake was prepared recently (ECan, unpublished 2008). The cause of the poor trophic state is unknown, but may arise from unusual natural causes.

A similar situation is monitored on the Chatham Islands where Lake Kaingarahu is similarly in perpetual algal bloom (and has been so for many decades), is largely in a wilderness area, surrounded by natural vegetation, and with little if any capacity for anthropogenic causes. Both lakes Rotorua and Kaingarahu are considered ‘dune lakes’, and both have very long water residence times (a particular feature you also point out). It is this latter feature that may allow such lakes to conserve and recycle any concentration of nutrients or other contaminants very effectively. We are also mindful of the similar example of Hamilton Lake in the Waikato region, where the arsenic applied as arsenite herbicide in the 1950’s has been conserved such that more than 80% of the chemical can still be accounted for within the lake 40-50 years later (NIWA unpublished).

The conserved nutrients in Lake Rotorua (and Lake Kaingarahu on the Chathams) could have arisen historically from any number of unusual processes such as natural high wildlife densities, mortality of wildlife (bird) aggregations, or a pocket of nutrients of historical, marine, or of geological origin within the dune formations. As with our earlier discussions it is important to distinguish 'natural perturbations' from 'anthropogenic effects', and it would appear appropriate to consider Lake Rotorua's state to be generated by natural causes or natural perturbations. In the circumstances it is therefore not appropriate to use the unusual Lake Rotorua example to set low targets on all lowland or dune lakes.

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Appendix: Lakes Summary

LID	Lake_name	Lake_surface_area (m^2)	ha	East_NZMG	North_NZMG	AquaticPlantDatabase LakeNumber	PredictedMacrophyteDepth
46564	'Lake Pukaki'	172735904	17273.59	2283162	5679850		15.18
47228	'Lake Tekapo'	96594312	9659.43	2310979	5698996		17.84
7409	'Lake Benmore'	75852992	7585.30	2286478	5634947		14.33
45514	'Lake Ohau'	59267700	5926.77	2259235	5658940	647	25.92
48451	'Lake Coleridge'	36875980	3687.60	2388218	5767173	556	32.4
7408	'Lake Aviemore'	28344322	2834.43	2295172	5617488		6.44
54738	'Lake Sumner'	13731126	1373.11	2445793	5833483	496	25.21
47892	'Lake Heron'	6945279	694.53	2362643	5746534	571	10.86
47193	'Lake Alexandrina'	6456601.5	645.66	2305464	5693438	619	12.1
12307	'Lake Waitaki'	5666427	566.64	2303504	5611688		6.76
47579	'Lake Forsyth (Lake Wairewa)'	5587549.5	558.75	2489581	5711625		3.27
45525	'Lake Ruataniwha'	3491598	349.16	2275797	5654626	1067	8.57
26477	'Lake Tennyson'	2325338	232.53	2487626	5889627	469	19.97
46835	'Tasman Lake'	2085847	208.58	2282859	5719312		10.28
39356	'Lake Taylor'	2068140	206.81	2447313	5826358	509	15.71
48660	'Lake Pearson'	2019388.5	201.94	2410832	5788399	534	10.76
41305	'Lake Clearwater'	1966490	196.65	2352183	5731997	582	5.39
41299	'Lake Emma'	1667881	166.79	2357108	5728437	589	1.63
39357	'Lake Sheppard'	1090157.5	109.02	2448559	5827070	507	9.95
48597	'Lake Lyndon'	883891	88.39	2404487	5766406	558	11.19
39364	'Loch Katrine'	778999	77.90	2444415	5831848	502	11.64
45503	'Wairepo Arm'	661780.5	66.18	2276905	5652501		6.34
48213	'Lake Selfe'	654373	65.44	2389692	5773127	551	18.12
25212	'Lake Guyon'	626317	62.63	2480903	5879756		8.33
48663	'Lake Grasmere'	623559	62.36	2410195	5793167	532	8.69
39297	'Lake Mason'	526387	52.64	2441996	5830184		7.14

LID	Lake_name	Lake_surface_area (m^2)	ha	East_NZMG	North_NZMG	AquaticPlantDatabase LakeNumber	PredictedMacrophyteDepth
41306	'Lake Camp'	437516	43.75	2353070	5730709	584	5.41
25994	Lake Rotorua' Kaikoura	432387	43.24	2557903	5866690		2.89
47198	'Lake Mcgregor'	370901.5	37.09	2307000	5693715	620	7.15
48669	'Lake Hawdon'	353622	35.36	2416383	5788633		5.44
48657	'Lake Marymere'	240036	24.00	2416762	5787194		8.97
45504	'Lake Middleton'	234998	23.50	2258550	5654100	651	5.9
48673	'Lake Sarah'	220044	22.00	2410313	5794662		5.21
45501	'Keland Pond'	196938	19.69	2276077	5652429		5.07
47860	'Lake Emily'	193435	19.34	2366774	5738063	578	2.7
48447	'Lake Georgina'	174515	17.45	2393918	5764587	560	5.47
39367	'Lake Marion'	99807	9.98	2447057	5836330	494	3.37