Resource Economics

Essential Freshwater Package: *Benefits Analysis*

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Prepared for

Ministry for the Environment

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1 Introduction

1.1 Purpose of this Report

This report examines the benefits of improving water quality under the Essential Freshwater (EFW) Package.[1] It is expected to result in costs because of the required changes to farm practices and land uses to reduce discharges. To compare with these costs, this report identifies the expected benefits and examines whether they can be measured in monetary terms. We review relevant literature and compile available data.

1.2 The Water Quality Problem

Freshwater quality has deteriorated in New Zealand from factors that include run-off or leaching of nitrogen, phosphorus, sediment and pathogens (particularly *E coli*).

- Nitrogen and phosphorus can cause excessive growth of periphyton (slime and algae) in rivers and toxic algae in lakes. This can reduce the aesthetic value of waterways, the diversity of aquatic life and the potential for recreational and commercial use (Table 1).

- Sediment reduces water clarity and smothers the beds of waterways to the detriment of freshwater species.

- Pathogens have impacts on human health via waterborne infections and illnesses for people in direct contact with water, such as when swimming.

Table 1 Problems associated with excess periphyton

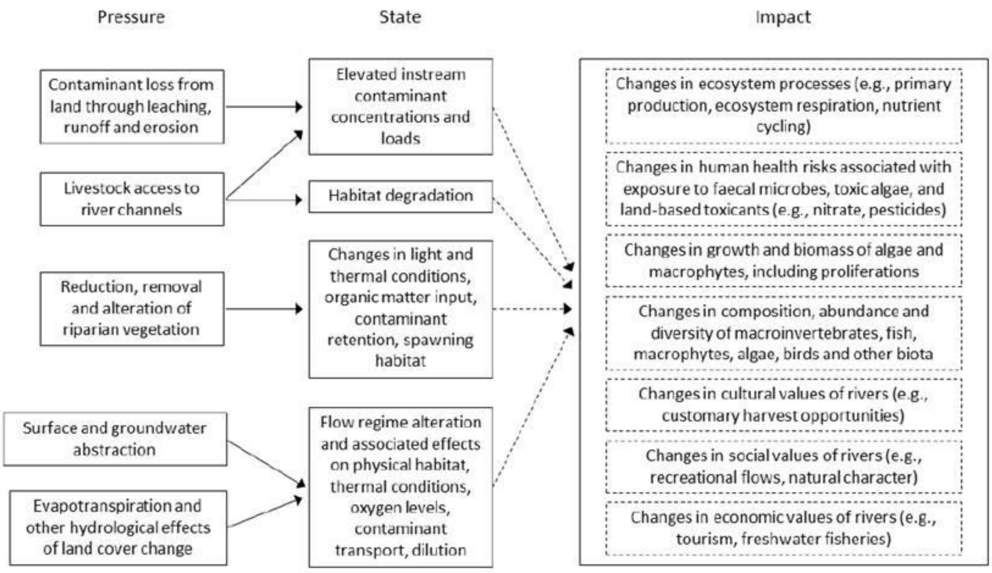
Instream value	Problem
Aesthetics	Degradation of scenery, odour problems
Biodiversity	Loss of sensitive invertebrate taxa through habitat alteration, possible reduction in benthic biodiversity
Contact recreation	Impairment of swimming, odour problems, dangerous for wading
Industrial use	Taste and odour problems, clogging intakes
Irrigation	Clogging intakes
Monitoring structures	Fouling of sensor surfaces, interferes with supply
Potable supply	Taste and odour problems, clogging intakes
Native fish conservation	Impairment of spawning and living habitat
Stock and domestic animal health	Toxic blooms of cyanobacteria
Trout habitats/angling	Reduction in fish activity/populations, fouling lures, dangerous for wading
Waste assimilation	Reduces stream flow, reduces ability to absorb ammonia, reduces ability to process organics without excessive DO depletion
Water quality	Increased suspended detritus, interstitial anoxia in stream bed, increased DO and pH fluctuations, increased ammonia toxicity, very high pH
Whitebait fishing	Clogging nets

Source: Biggs (2000)

[1] Ministry for the Environment and Ministry for Primary Industries (2018)

Overall the effects of contaminants in waterways are to change ecosystem structure and dynamics, with consequent impacts on recreational, customary and commercial use, and on the benefits people gain from being near freshwater or even from just knowing about the reduced quality (Figure 1). The EF Package aims to improve the quality of freshwaters in New Zealand relative to what it would be otherwise.

Figure 1 Impacts of Activities Affecting Freshwater Environments



Source: Larned *et al* (2018)

Environment Aotearoa 2019,[2] which is a synthesis report on the state of the environment, assessed the state of freshwater in 2013-17 against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. It identified that 50-90% of the total river length in agricultural areas[3] exceeds the relevant guideline values for water quality in a natural state; this compares to 30% of rivers in native forest areas (Table 2).

Table 2 Modelled river water quality in pastoral and native land catchments (2013-17)

		Median value		**River length (km) and % that does not meet ANZG DGV**			
Water quality variable	Units	Pastoral	Native	Pastoral		Native	
Total nitrogen	mg/m3	738.6	115.9	162,475	(-86%)	57,027	(-29%)
Nitrate nitrogen	mg/m3	246.6	25.6	155,000	(-82%)	26,610	(-13%)
Ammoniacal nitrogen	mg/m3	8.3	4	94,237	(-50%)	29,464	(-15%)
Total phosphorus	mg/m3	32.5	8.3	169,142	(-90%)	50,977	(-26%)
Dissolved reactive phosphorus	mg/m3	14.6	4.4	144,191	(-77%)	45,270	(-23%)
E coli	cfu/ 100ml	195	13.3	47,314	-25%	1,117	-0.60%
Turbidity	NTU	2.9	1.3	117,343	-62%	22,962	-12%
Clarity	m	1.7	3.3	13,499	-7%	1,467	-1%

Source: Ministry for the Environment & Stats NZ (2019)

[2] Ministry for the Environment & Stats NZ (2019)

[3] Land is classified into four classes: pastoral (ie agriculture), exotic forest, native and urban.

Water quality has been reducing because of changes in agriculture, and particularly:[4]

- Changes in stock type - fewer sheep and more cows (and cattle excrete more nitrogen per animal than sheep)
- Increases in stock intensity per hectare
- More nitrogen fertiliser applied
- More irrigated land (greater irrigation take reduces water levels in rivers and streams and concentrates pollution loads).

1.3 Existing Policy – the NPS-FM

Freshwater management is the responsibility of councils under the Resource Management Act 1991. National direction is provided through the National Policy Statement for Freshwater Management (the NPS-FM). Originally introduced in 2011, the NPS-FM was amended in 2014 and in 2017. Councils must fully implement the objectives and policies of the NPS-FM by 2025, or 2030 if they cannot complete the process to sufficient quality by 2025.

A review of the NPS-FM after its introduction suggested it would not achieve the sustainable management of freshwater resources.[5] The Ministry for the Environment (MfE) suggests the problems include:

- problems with interpretation and implementation, including poor engagement with iwi/hapū in some locations;

- few regulatory options for councils to use to influence or control activities with the most impact on water quality, particularly agriculture; and

- standards not stringent enough – slow adoption of quantitative and enforceable water quality limits in the majority of regional plans, and the slow application of these limits to resource users.

The result of these shortcomings is that water quality is continuing to degrade in places, or it is expected to take a long time to achieve desired outcomes.

1.4 The Essential Freshwater Package

In response to the problems identified with the NPS-FM, the EFW package[6] would introduce a new set of regulatory requirements, including tightened standards (or bottom lines), and more controls over on-farm management via requirements for stock exclusion from riparian strips. It aims:

- in the short run, to stop further degradation of freshwater quality and to start making improvements so water quality is materially improving within five years; and

- in the longer run, to bring freshwater resources, waterways and ecosystems to a healthy state within a generation.

[4] Ministry for the Environment & Stats NZ (2019)
[5] Ministry for the Environment (2019c)
[6] Ministry for the Environment (2019a)

It will also address water allocation issues.

Three regulatory tools have been identified.[7]

- changes to the NPS-FM;
- the creation of a new National Environmental Standard (NES) (which would impose regulations quickly to limit potential further decline); and
- the creation of new regulations[8] (which can take immediate effect from their commencement date and are a more appropriate vehicle for some interventions).

They would be expected to improve policy direction, set thresholds or bottom lines, require adoption of good practice, improve monitoring and reporting on freshwater, and support people in implementing these changes. These include:

- Nitrogen and Phosphorus:
    - more stringent bottom-lines for Dissolved Inorganic Nitrogen (DIN) and Dissolved Reactive Phosphorus (DRP) which will apply in soft-bottomed rivers in some lowland agriculturally-dominated areas; and
    - reducing excessively high nitrogen leaching (a nitrogen cap) eg using per-hectare nitrogen leaching thresholds (option 1) and a national fertiliser cap (option 2);

- **Sediment:** bottom lines for sediment which will require reductions in erosion;

- ***E coli*:** a requirement to set target states for *E coli* above a national bottom line of 550 *E coli* per 100 ml for primary contact sites during the swimming season;

- **Māori values:** creating a 'mahinga kai' compulsory value and a new value category for 'tangata whenua' values in the National Objectives Framework;

- **Wetlands:** new rules to prevent further loss and degradation of remaining natural wetlands;

- **Stock exclusion**: regulations requiring farmers to exclude all cattle, pigs and deer from rivers, lakes, wetlands and drains across low-slope New Zealand.

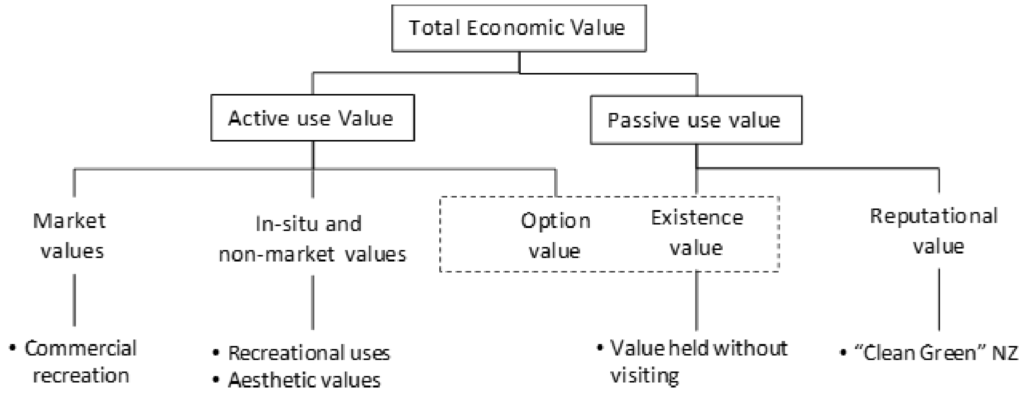
In this report we are examining the expected benefits of the package, quantifying these where possible. We discuss some identified benefits more qualitatively, and make links to other components of the impact analysis which will include benefit analyses.

1.5 Benefits to be Evaluated

Our interest is in estimating the change in the full set of values obtained from improvements in the quality of freshwater, ie everything that changes people's wellbeing. Figure 2 provides a summary of the values considered.[9]

[7] Ministry for the Environment (2019c)
[8] The regulations would be under Section 360 of the Resource Management Act 1991.
[9] An alternative set of values is provided by Gluckman (2017)

Figure 2 Freshwater's contribution to total economic value



Source: adapted from Sharp and Kerr (2005)

Total economic value (TEV) includes active use and passive use values, where:

- **active use** values derive from actual use of the water resource via commercial and non-commercial (eg recreational) activities. The physical presence of the water (and its quality) is vital to the realisation of the value.
    - Market values are those obtained by those whose business activity depends on the quality of freshwater, such as those with commercial recreational businesses;
    - Values are also obtained by people who visit freshwater sites for recreational purposes; typically these values are not expressed in a market, so they must be measured indirectly;

- **passive use** values are values that pertain more to the fact of existence of the water resource. It includes:
    - "existence value", which is the value from knowing of the quality of an ecosystem or site which you may never visit; and
    - Reputational value is the indirect value which clean freshwater contributes to New Zealand's reputation for environmental quality and which might be expressed via a price premium in some markets for export goods (including tourism visits).

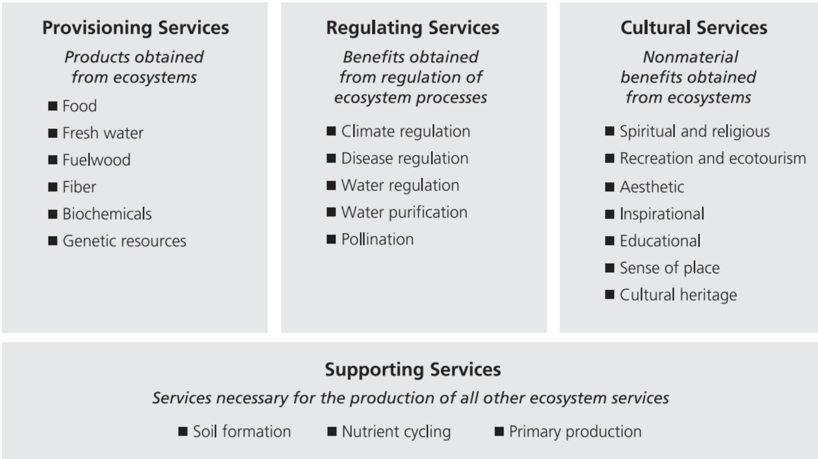
- **Option values** which represent the value of retaining an option to use a resource in the future. They represent the value of not foreclosing options and may pertain to active or passive uses.

Although these categories of value are widely discussed in the literature, in practice it may not always be possible to separate them out. Passive uses, in particular, are often combined into a single existence value category;[10] option values are likely to be best retained by maintaining high water quality and there is a strong correlation with the values expressed as existence value.

The concept of ecosystem services if often used in environmental valuation literature alongside the TEV concept (eg Pascual et al, 2010). Ecosystem services is a framework under which the relationship between the functioning of an ecosystem and the services provided to people is divided into four categories – provisioning, regulating, cultural and supporting (Figure 3).

[10] Sharp and Kerr (2005)

Figure 3 Ecosystem Services



Source: Millennium Ecosystem Assessment (2005)

The concept is that freshwater and other ecosystems have a vital role in the functioning of the whole ecological system of which human activity and the economy is a part. The impacts of changes in water quality can thus affect values well beyond those immediately identified.

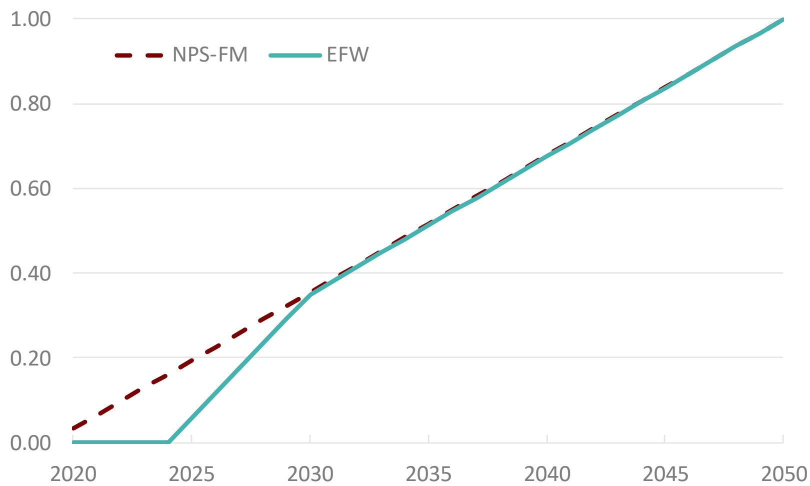
1.6 Speed of Implementation

For quantitative analysis we assume the response to the policy will increase over time. The Essential Freshwater package is expected to start having effects from approximately 2025. However, current policy in response to the NPS-FM is expected to have effects also. The assumptions are shown in Figure 4.

- The NPS-FM is assumed to be introduced in a straight line between now and 2050.
- The EFW is assumed to be introduced rapidly from 2025 so that it is 35% implemented by 2030. It is then introduced in a straight line to achieve full implementation in 2050.

However, for modelling purposes, rather than assume nothing happens under the EFW scenario until 2025, the assumption is that the same effort as assumed under the NPS-FM occurs.

Figure 4 Assumed rate of implementation



The stock exclusion policy is a separate part of the policy package and is expected to be introduced much more quickly. Following MfE advice, we have assumed 33% implementation by 2021, 67% in 2022 and full implementation in 2023.

1.7 Discount Rates

In this analysis we use a central discount rate of 3% and with sensitivity analysis using 0%, 1% and 6%. Below we briefly discuss the basis for these rates.

1.7.1 Rationale for Discounting

When analysing costs and benefits in a CBA for policy purposes, we are measuring changes in total community wellbeing. Wellbeing is assumed to be the result of 'consumption', using a broad definition of that term. Freshwater policies have costs because they require more expenditure (on fences, supplementary feed etc) or result in reduced profits (eg because of lower stocking rates reducing total production); there are opportunity costs because the effect is to reduce the potential for consumption of goods and services that provide wellbeing. Similarly, on the benefits side, everything from which people obtain wellbeing is said to be 'consumed', eg people might 'consume' a view or the knowledge of water quality improvements in places they will never visit; the policies are expected to lead to increased consumption of environmental goods.

Wellbeing is affected by <u>what</u> people consume, <u>how much</u> they consume and <u>when</u> they consume. Discounting is a means of adjusting the size of costs and benefits that arise in different time periods to account for preferences over the timing of consumption.

Discounting is usually used to reduce the value of future costs and benefits. This is because people generally prefer to consume sooner rather than later and, consistent with assumptions of rational decision making, this is assumed to mean people obtain greater wellbeing benefits from earlier consumption. Although several authors have questioned whether time preference is rational (eg Pigou, 1932; Ramsey 1928)[11] and/or if it should be used for public decision making (Samuelson, 1937), mostly there is acceptance of a theoretical basis for using a discount rate greater than zero and for using it in public policy decision making.[12] For example, Nicholas Stern who examined the use of very low discount rates in the context of climate change policy affecting future generations, suggested a low but positive rate on the basis of some less than zero probability of human extinction favouring current consumption.[13]

Methodologies

There have been two main methodologies for deriving a discount rate for public policy purposes.

- The **social rate of time preference** (SRTP) measures time preferences directly – how much people prefer to consume now rather than later. Because people usually prefer to consume earlier in time, and for adverse effects to be delayed, there is a cost when consumption is shifted to a later time, and a benefit when it is brought forward. SRTP analyses often also assume that people in the future will be richer and therefore the wellbeing gained from an

[11] Arthur Pigou (1932) argued that someone's satisfaction obtained from consuming this year rather than next, is balanced by the satisfaction obtained next year from consuming then, rather than this year! He suggests "*it implies that people distribute their resources between the present, the near future and the remote future on the basis of a wholly irrational preference*" (p25).
[12] Arrow *et al* (1995)
[13] Stern (2006)

additional dollar's worth of consumption will be less than it is for current (and assumed poorer) individuals.[14]

- The **social opportunity cost of capital** (SOC) examines returns on investment in which investing money, which might otherwise have been used to pay for consumption goods now, obtains a return enabling greater future consumption.

The NZ Treasury has generally used the SOC as the basis for setting discount rates for use in public policy,[15] currently recommending use of a 6% default rate.[16] However, for sensitivity analysis they have used a 3% rate in their CBAx tool, which is a spreadsheet model that contains a database of values to help agencies measure impacts and undertake CBAs.[17] These discount rates are in real terms, ie they apply to monetary values using current dollars, so at 2% inflation they are equivalent to rates of approximately 7.9% and 4.9% in nominal terms.

Some studies in New Zealand have attempted to measure the SRTP, including a (real) rate of 4.4% estimated in 2006 for the national energy strategy,[18] a range of 2.7 to 4.2% developed in the context of decisions on investments in the national electricity transmission grid,[19] and 3% in a study relating to transport infrastructure investments.[20] Auckland Council adopted a rate of 4% for CBAs, building on advice from NZIER for a rate of between 3% and 4%.[21]

For analysis, we have adopted:

- a rate of 3% as the central discount rate. It reflects analyses of the SRTP in New Zealand and uses the low rate used by Treasury in in its CBAx model.

- a high rate of 6%, based on Treasury's default rate; and

- a low rate of 1%, reflecting doubts over the rationality of discounting.

[14] Recent analyses in the context of climate change have questioned this assumption.
[15] NZ Treasury (2015)
[16] https://treasury.govt.nz/information-and-services/state-sector-leadership/guidance/financial-reporting-policies-and-guidance/discount-rates
[17] NZ Treasury (2019)
[18] Ministry of Economic Development (2006)
[19] Castalia (2006)
[20] Parker (2009)
[21] Chief Economist Unit (2013)

2 Existing Studies

Three studies have been undertaken recently to estimate the costs and benefits of proposed components the EF package. These studies, which include estimates of benefits in monetary terms, assess the impacts of:

- stock exclusion on human health;
- *E coli* bottom lines on human health; and
- sediment discharge reductions on water clarity.

We summarise these studies below, but first we set out the assumptions which underly monetary valuation of non-market benefits.

2.1 Assumptions

In this section we examine non-market analyses which have estimated people's willingness to pay (WTP) for water quality improvement. WTP estimates assume that achieving greater environmental quality will entail costs, ie that the community as a whole obtains less of something else that is valued, such as the profits from agricultural activities. WTP is then a measure of how much people would be willing to give up to obtain improvements in environmental quality.

Monetary valuation of improved water quality brings a set of assumptions or perspectives.

- Valuation necessarily takes a human-centric perspective. The values are those obtained and expressed be people and involve a measure of how they trade-off one potential use of a resource for another. Any intrinsic values of the environment (eg, as included in Article 7 of the Resource Management Act 1991)[22] are therefore not addressed.

- The values are based on revealed or stated WTP for improved water quality. This assumes landowners have the right to discharge but the wider public must demonstrate what they would be willing to give up (eg to persuade the rights owners) to reduce the discharges. Under a different assumption in which there was an established right to clean water, the compensation the public would be willing to accept to allow water quality reductions would be expected to produce higher valuations.[23] The RMA (Section 15) states that no person may discharge any contaminant into water unless allowed by a regulation, a plan, or a resource consent. Thus, the question of how any rights to discharge should be defined needs to be addressed in each region or nationally, and this decision has implications for the valuation approach.

- The values are those of individuals, rather than the community. Several authors have suggested that people might state different levels of preference if responding as members

[22] intrinsic values are defined in the RMA (Article 2) in relation to ecosystems as "those aspects of ecosystems and their constituent parts which have value in their own right, including—(a) their biological and genetic diversity; and (b) the essential characteristics that determine an ecosystem's integrity, form, functioning, and resilience"

[23] See discussions of the difference between WTP and willingness to accept (WTA) compensation, eg in Pearce *et al* (2006)

of a group rather than as individuals.[24] However, there are few empirical studies from this perspective, and none identified for this report.

2.2 Stock Exclusion

Analysis of the monetary benefits of fencing for stock exclusion was undertaken by Lincoln University (Tait *et al,* 2016). This analysis used inputs from a NIWA study of the expected water quality outcomes from stock exclusion[25] and provided inputs to a National Stock Exclusion Study (NSES), which included a cost benefit analysis (CBA) by the Ministry of Primary Industries (MPI).[26] A revised stock exclusion policy is being considered as part of the EF package.

NIWA, with AgResearch, developed an *E. coli* Catchment Load Model (ECLM) which predicted annual in-stream *E. coli* loads as a function of land use (including stock type) and catchment characteristics. In the model, fencing has an associated load reduction factor, or removal efficiency, which decreases discharge rates for each stock type. The model output from simulating the stock exclusion policy included river lengths in different water quality bands based on *E. coli* concentrations.

To quantify these improvements using monetary values, Tait *et al* (2016) used a choice experiment, which is a type of stated preference survey. It presented a national representative sample of adults (18 and over) with a series of choice tasks in which they were asked to choose their preferred option between some hypothetical animal management programmes for waterways with different costs and different water quality outcomes relating to human health risk, ecological quality (measured using the Macroinvertebrate Community Index or MCI – see Box 1) and water clarity (visible metres). An example choice task in the survey is shown in Figure 5. Under each of the categories the pie charts represent the proportion of rivers or lakes which fall into different quality categories. Subsequent analysis of the data was used to estimate the willingness to pay for the different water quality attributes (Table 3).

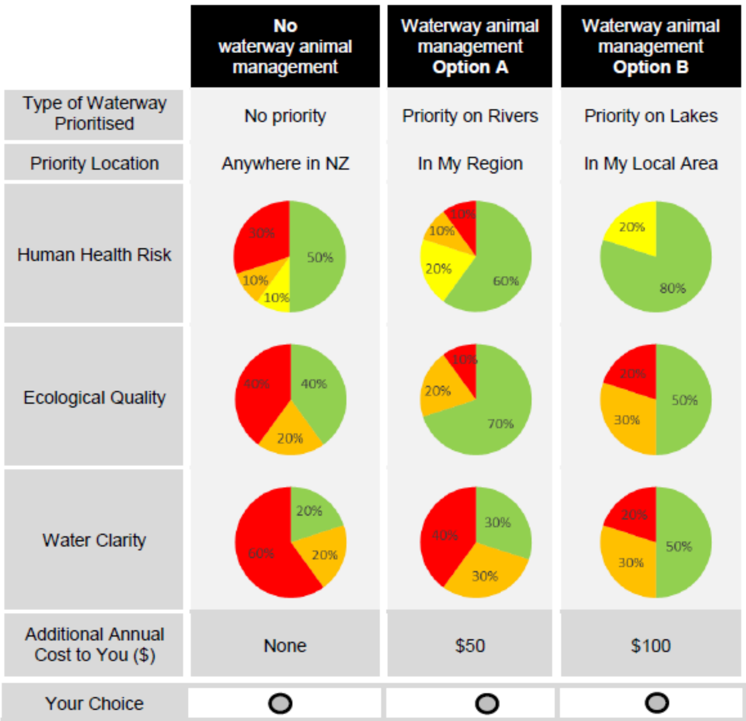
Table 3 Willingness to pay ($/adult/year) for a 1% increase in water quality outcomes

Attribute	Level	Median (2015)	Range (2015)[a]	Median (2019)	Range (2019)[a]
Human Health Risk	1:20	$0.70	$0.22 - $1.28	$0.74	$0.23 - $1.36
(chance of infection)	1:100	$1.15	$0.65 - $1.65	$1.22	$0.69 - $1.75
	1:1,000	$3.31	$2.79 - $3.83	$3.52	$2.97 - $4.07
Ecological Quality	Moderate (81-99)	$2.14	$1.73 - $2.54	$2.27	$1.84 - $2.7
(MCI)	Good (100+)	$5.68	$5.41 - $5.93	$6.04	$5.75 - $6.3
Water Clarity	Moderate (1.2m – 2.4m)	$4.13	$3.64 - $4.62	$4.39	$3.87 - $4.91
(metres)	Good (2.5m or more)	$7.39	$6.93 - $7.86	$7.86	$7.37 - $8.36

[a] Range = 5th and 95th percentiles
Note: All values inflated to Q4 2019 from Q3 2015 values (survey in September 2015) using CPI: Statistics New Zealand, Infoshare Database: CPI Index All Groups for New Zealand: Q3 2015 = 982; Q4 2019 = 1044
Source: 2015 values from Tait *et al* (2016)

[24] Sagoff (1988); Wilson and Howarth (2002); Lo and Spash (2011); Turner (2006)
[25] Semadeni-Davies and Elliott (2016)
[26] Grinter and White (2016)

Figure 5 Example choice set



Source: Tait et al (2016)

Box 1 Macroinvertebrate Community Index

The Macroinvertebrate Community Index (MCI) is used as a measure of stream "health" and is calculated as the sum of scores based on the presence of different types of invertebrate (Stark 1985; Stark and Maxted 2007). Those common in unpolluted streams are given high scores and those common in polluted streams are given low scores.

$$MCI = \frac{\sum_{i=1}^{i=S} a_i}{S} \times 20$$

Where S = the total number of taxa in the sample, and a_i is the tolerance value (measure of the sensitivity to pollution and habitat disturbance) for the ith taxon.

Related indices include the Quantitative MCI (QMCI)

$$QMCI = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

Where n_i is the abundance for the ith scoring taxon and N is the total of the coded abundances of the total sample.

Source: Stark and Maxted (2007)

Although Tait *et al* provided values for ecological quality and water clarity, the analysis of the benefits of the stock exclusion policy was limited to the impacts on human health. The analysis of human health impacts was possible because of the predictive model (ECLM) that linked the policy to the effects on *E coli*. There was no similar model identified to predict the impacts on MCI or water clarity.

The estimated benefits of different variations of the stock exclusion policy are shown in Table 4; it assumes over 95% of dairy land that could fenced, is already fenced, 70% for sheep & beef and 73%

for deer. The closest policy to the new proposed stock exclusion policy is Option 5, ie it does not include fencing of steep land.[27]

Table 4 Annual and present value of benefits of stock exclusion policy options (discounted at 8% over 25 years)

Stock exclusion options	Marginal annual benefits ($m)	Present value ($m)	Cumulative PV ($m)
Baseline: Current fencing, including regional council requirements to be implemented by July 2017			
Baseline plus: Dairy cattle on dairy platforms by 2017 on flat and rolling land for Accord waterways	$5.7	$65.3	$65.3
Option 2 plus: Dairy cattle grazing on land owned by dairy farmers by 2020 on flat and rolling land for Accord waterways	$5.9	$68.0	$133.3
Option 3 plus: Dairy cattle grazing on land owned by a third party by 2025 on flat and rolling land for Accord waterways	$10.8	$124.5	$257.8
Option 4 plus:Beef cattle excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	$62.1	$716.1	$973.9
Option 5 plus: Deer excluded by 2025 on flat land, and 2030 on rolling land for Accord waterways	$0.8	$9.5	$983.4
ALL: Exclude all cattle (dairy and beef) and deer into steep country (slopes up to 28 degrees) by 2017	$207.0	$2,386.4	$3,369.8

Source: Tait *et al* (2016); Grinter and White (2016)

In its interim Regulatory Impact Analysis (RIA), MfE suggests that, because of the inclusion of land beside streams less than 1 metre wide, the EF package would exclude more stock than assumed in the 2016 analysis, such that the benefits would exceed the $983 million estimate for the value of exclusion from flat land.[28] However, the EF package as agreed by Cabinet does not include this extension.

In our analysis of stock exclusion policy, we use the results of a new analysis by NIWA with the values from Tait *et al* (2016).

2.3 E Coli Bottom Lines

In the interim RIA, MfE analysed the benefits of the *E coli* element of the EF package, focussing on the bottom lines as defined in Table 5 (option 1 in the Interim RIA).

The MfE analysis used estimates of existing risk levels using Land Air and Water Aotearoa (LAWA) data[29] which contained the Faecal Indicator Bacteria results from the 2015/16 - 2017/18 summer bathing seasons. There are 292 monitored sites, and 206 for which a 95th percentile was calculated (as required for health risk classification - Table 5). *E coli* levels in 11.5% of sites are in the “excellent” band of the guidelines, 13.5% are “good”, 22.6% are “fair” and 52.4% are “poor” (where the guidelines recommend the public is warned against swimming). All catchments upstream of sites that are “poor” have significant amounts (over 50%) of pastoral land use. In addition, there is a wastewater treatment plant (WWTP) discharging to freshwater (either always or sometimes) upstream of 52 sites; in 50% of these sites, *E coli* levels exceeded the recommended national bottom line.

[27] The estimated total benefits ($983.4m) correspond to the benefits of $1,847m in Tait et al (2016) minus the status quo benefits ($863.6m) – see Tables 7 and 8 in Tait *et al*.
[28] Ministry for the Environment (2019c)
[29] https://www.lawa.org.nz/download-data

Table 5 *E coli* attribute table for Appendix 2 of the NPS-FM

Value	**Human health for recreation**	
Freshwater Body Type	Primary contact sites in lakes and rivers (during the bathing season)	
Attribute	Escherichia coli (E. coli)	
Attribute Unit	95th percentile of E. coli/100 ml (number of *E. coli* per hundred millilitres)	
Attribute State	Numeric Attribute State	Narrative Attribute State Assuming '% of time' equals '% of samples'
Excellent	≤ 130	Estimated risk of Campylobacter infection has a < 0.1% occurrence, 95% of the time
Good	131 - 260	Estimated risk of Campylobacter infection has a 0.1 – 1.0% occurrence, 95% of the time
Fair	261 – 550	Estimated risk of Campylobacter infection has a 1 – 5% occurrence, 95% of the time
National bottom line	550	
Poor	> 550	Estimated risk of Campylobacter infection has a > 5% occurrence, at least 5% of the time

Source: Ministry for the Environment (2019d)

MfE analysed the costs of the policy, assuming stock exclusion (by fencing) from grassland areas and targeting runoff from areas like laneways (where stock walk to the milking sheds) and yards.

The benefits were estimated using national data[30] on notified cases (Table 6) and cost data from a Havelock North campylobacteriosis outbreak in 2016. Notified cases are those notified to the Medical Officer of Health, as required by law for these and other diseases.[31] The data in Table 6 are the number of cases notified, those hospitalised and the number that were recorded as being associated with contact with recreational water. For campylobacteriosis, 427 were recorded as being associated with water and 1,970 were recorded as not associated with recreational water contact, so the number of notified cases with contact with recreational water as a risk factor is estimated at 427-4,512.[32]

Table 6 Summary of water borne notified diseases and contact with recreational water

Disease	**Cases notified**	**Cases hospitalised**	**Contact with recreational water**
Campylobacteriosis	6,482	510	427 - 4,512
Salmonellosis	1,119	220	135 - 669
Cryptosporidiosis	1,192	66	219 - 620
Giardiasis	1,648	37	250 - 1,073
Total	10,441	833	1,031 – 6,874

Source: ESR (2019) in Ministry for the Environment (2019d)

MfE suggests, across all four diseases, the actual number of cases could be ten times the notified number of cases because many people do not present to doctors. In the Havelock North campylobacteriosis outbreak in 2016, there were 964 notifications, but estimates of actual cases included 5,540 (based on a resident survey) and 2,827 – 7,326 (with a mean of 4,928) based on ratios between notified and actual cases from the literature.[33] MfE considered other studies, including the

[30] The data are taken from ESR (2019)
[31] https://www.health.govt.nz/our-work/diseases-and-conditions/notifiable-diseases
[32] 4,512 = 6,482 – 1,970
[33] Moore *et al* (2017)

results of an Acute Gastrointestinal Illness (AGI) study which suggested only 0.4% of cases were notified.[34] The Havelock North infection may have resulted in greater percentage notification because of the significant local and national publicity about the outbreak, whereas our interest here is in more isolated infection incidents.

A study of the Havelock North outbreak was used as the source of costs per case. Total costs were estimated to be $21 million for an estimated 5,088 households,[35] including those to households, local and central government, business and the health sector. Because the Havelock North outbreak was concerned with drinking water, MfE did not include the costs of households purchasing bottled water, the costs to local and central government, or the costs to NGOs. This reduced the costs to $12.8 million in total and to approximately $2,500/household affected. The per household costs were combined with the estimated national cases (the contact with recreational water numbers in Table 6 were rounded to 1,000 – 7,000 and multiplied by 10), multiplied by just under half on the basis of an estimate of the number of households within 20 km of a monitored recreational site (2.2 million people), and rounded down to $10-$80 million (see calculations in Table 7).

Table 7 Costs of freshwater-borne infections

	Low	High
Notified cases	1,000	7,000
Actual cases (x10)	10,000	70,000
Affected by freshwater	46%	46%
Cost per case	$2,500	$2,500
Total annual cost ($m)	$11.5	$80.2

Source: estimated from numbers in Ministry for the Environment (2019d)

These costs represent the total cost of infections (which might be eliminated if there were no infections), but are not an estimate of the benefits of the EF package.

Our preference is for the results using the WTP study as it would be expected to include the full set of benefits that people obtain from improvements in the quality of swimming water, including those that accrue to those who don't visit the freshwater sites but benefit from knowing it is clean.

The MfE analysis does suggest that there are costs to the health system that would be additional to those that an individual would face, and presumably which would be external to their expressed WTP. However, we do not have a basis for estimating the level of this cost (and cost savings as a benefit) in addition to the WTP numbers.

2.4 Sediment Discharge

An analysis of the impacts of the EF package on sediment discharges was undertaken by Landcare Research[36] building on initial physical impact analysis by NIWA.[37]

NIWA developed and used modelled relationships between sediment loading and turbidity and visual clarity, which they describe as having tolerable levels of uncertainty. These were used to map where proposed thresholds are expected to be exceeded, and then to estimate the reduction in

[34] Lake *et al* (2009)
[35] Moore *et al* (2017)
[36] Neverman *et al* (2019)
[37] Hicks *et al* (2019)

mean annual sediment load required to meet the threshold values. The modelling was thus able to predict the water clarity outcomes of the sediment control components of the EF package (Table 8). To combine the water clarity improvement estimates with the benefit values for water quality improvement in Tait *et al* (Table 3), Landcare also estimated the percentage of the clarity improvements (to meeting limits) that started in waters classified as poor, moderate, or good (the final three columns in Table 8). Thus, of the waterbodies in Auckland that changed from violating their limits to achieving them, only 1% were good or poor, while 98% were moderate.

Table 8 Percent of Regions waterways meeting water clarity limits and % that meet limits from different starting positions

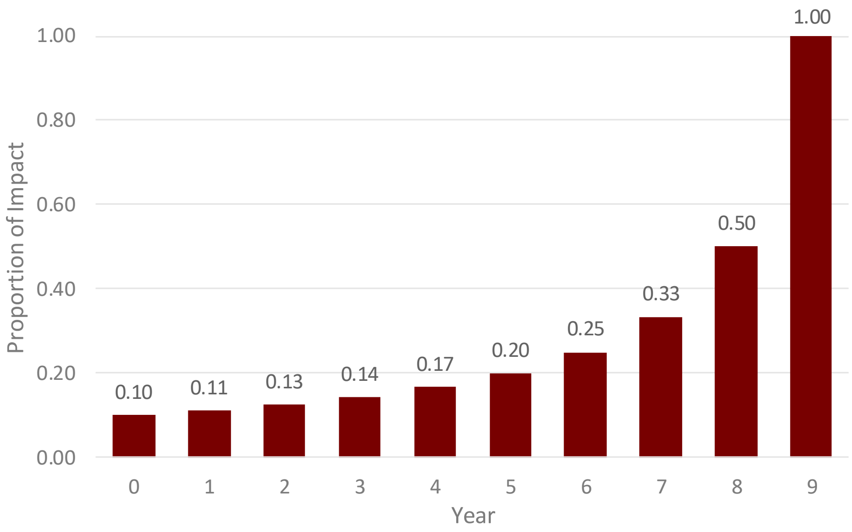
Region	% Before Mitigation	% After Mitigation	% Point Change	% Good	% Moderate	% Poor
Auckland	88.4	89.2	0.8	1.1	97.9	1.1
Bay of Plenty	91.9	93.9	2	48.8	51.2	0
Canterbury	82.8	84.5	1.7	83.5	16.5	0
Gisborne	77	84.9	7.9	88	12	0
Hawke's Bay	91.3	93.5	2.2	65.9	34.1	0
Manawatu Whanganui	72.5	72.6	0.1	84.1	15.9	0
Marlborough	94.8	96.9	2.1	94.9	5.1	0
Northland	86.8	88.8	2	0.2	91.5	8.4
Otago	78.3	82.7	4.4	45.8	32.4	21.8
Southland	73.3	74.4	1.1	4.4	67.2	28.3
Taranaki	88.6	89.4	0.8	1.5	98.5	0
Tasman/Nelson	96.5	96.5	0	100	0	0
Waikato	63.2	73.4	10.2	9	44.7	46.4
Wellington	87.9	93.3	5.4	76.3	23.7	0
West Coast	91.4	91.5	0.1	39.1	60.9	0

Source: Neverman *et al* (2019)

In estimating the benefits, they note that although much of the modelling is static in nature, ie the environmental effects of policy are modelled to occur instantaneously (or the results are shown only for when fully implemented), they assume it takes time for implementation and model the benefits as gradually ramping up in the first 10 years. They apply a formula of 1/(10-i), where i=the year; the effect is shown in Figure 6; from year nine the full benefits are obtained.

Taking these improvements, and the lagged benefits into account, they estimate total benefits by region and nationally at different discount rates (4% and 6%) over 50 years. Total benefits were estimated at $504 million (4% discount rate) and $335 million (6%) (Table 9). Over 50% of the benefits were estimated to arise in Wellington (33%) and Waikato (19%), with a further 25% in Canterbury and Auckland regions.

Figure 6 Assumed ramping up of implementation and impacts



Source: assumptions in Neverman *et al* (2019)

Table 9 Net present value ($ million) of benefits from water clarity changes from sediment policy

Region	4% Discount Rate	6% Discount Rate
Auckland	$59.4	$38.5
Bay of Plenty	$26.7	$17.8
Canterbury	$64.6	$42.7
Gisborne	$16.5	$11.1
Hawke's Bay	$14.3	$9.6
Manawatu Whanganui	$1.5	$1.0
Marlborough	$5.0	$3.4
Northland	$8.7	$5.8
Otago	$38.4	$25.7
Southland	$2.1	$1.4
Taranaki	$2.9	$2.0
Tasman/Nelson	$0.1	$0.0
Waikato	$98.0	$64.9
Wellington	$165.8	$110.8
West Coast	$0.2	$0.1
Total	$504.2	$334.9

Source: Neverman *et al* (2019)

The large value for Wellington reflects the 5.4 percentage point increase in waterways meeting limits (Table 8), combined with a relatively large population.

As with the analysis of stock exclusion policy, this analysis was possible because the physical modelling could produce a relationship between the policy changes and changes in a water quality indicator for which values had been measured, ie visual clarity.

There are some assumptions adopted by Landcare which we do not adopt in using the Tait *et al* values.

- Landcare scaled up the water clarity values to the regional level using household numbers, rather than the adult (18+) population as originally used by Tait *et al* and in the NSES CBA.[38]

- Landcare adjusted the regional estimates of WTP by regional median household income, which assumes that WTP for freshwater quality increases with income. However, there is a strong argument for adjusting values in the other direction, with the marginal benefit to low income households being valued more highly.[39] This latter approach assumes "*the benefit that a poor person derives from another dollar of income, and therefore from another dollar of expenditure, may be higher than the benefit derived by a rich person*";[40] and the same would be assumed to apply to a dollar's worth of wellbeing derived from an improvement in water quality. However, in the absence of data on appropriate weightings and because of our interest largely in national level impacts, we do not make any regional adjustments to WTP in this study.

- We use a different rate of assumed policy implementation (see Section 1.6 rather than Figure 6.

[38] Tait *et al* (2016) used the adult population multiplied by 79% to account for the 21% of respondents who had a WTP of zero.
[39] Adler (2016)
[40] NZ Treasury (2015), p47

3 Non-Market Values

In this section we review non-market values in the literature and the reasons for using the values from Tait *et al* (2016). We then use these values to estimate the benefits of improvements in human health, water clarity and ecological health.

3.1 Methodology Issues – Benefit Transfer

The benefits of environmental improvement are often highly site-specific, reflecting ecological factors and proximity to human populations. Studies which provide values may be of individual sites, eg the recreational values of a specific river.[41] Using benefit estimates from other locations (benefit transfer) can provide values in the right order of magnitude.[42]

Benefit transfer methods vary in their complexity, with the simplest approaches using values from elsewhere (direct transfer), and others adjusting the transferred values to take account of local factors (eg benefit function transfer).[43] But despite increasing sophistication of approaches, the values are still approximate and there are large potential errors or inaccuracies.[44]

The potential for errors is of obvious concern to this and other studies that are seeking to use benefit transfer as the basis for values. However, relevant to this current work and many other economic analyses, the expectation is that decisions will be made anyway, regardless of whether benefit values have been derived using a valid methodology. There is therefore a question over whether decisions are better made with no benefit data or with data derived using a poor methodology.

3.2 Valuation Data

There are a large number of studies which have identified monetary values for recreational use (active and passive) of specific waterways. Usually these will combine estimates of the value of a recreational day with estimates of numbers of recreational trips (or changes in trip numbers). These values are difficult to use in the absence of data on recreational activity levels using freshwater (see Annex A for a summary of available data) and changes in visitor numbers (if any) expected to result from improved quality.

A few NZ studies have summarised the benefit valuation literature relating to freshwater quality and we do not repeat this here. An initial literature review and gap analysis for the Ministry for the Environment (MfE)[45] identified exiting values that were used in a subsequent analysis of the benefits of water quality improvements in Southland.[46] In contrast, and reflecting the potential for errors, a review to provide inputs to a CBA of improvements in water quality for the Waikato River, suggested that the available values were site-specific and could not be used elsewhere.[47]

The Southland study transferred values directly from other parts of New Zealand without adjustment either for location or to take account of the impacts of increased supply on total consumption, while noting the problem of substitution (improvements in one river may lead simply to a shift in

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[41] See, for example, Kerr & Swaffield (2007); Marsh and Phillips (2012); Sheppard et al (1993)
[42] Sharp and Kerr (2005); Barbera (2010)
[43] Sharp and Kerr (2005)
[44] Rolfe *et al* (2015); Kerr and Sharp (2003a)
[45] Denne *et al* (2011)
[46] Denne *et al* (2013)
[47] Marsh and Mkwara (2013)

recreational activity from another). The assumption was that direct transfer would provide results that were in the right order of magnitude, and therefore would assist decision-making.

Harris *et al* (2016) criticised this approach, for its failure to take account of the shape of the demand curve (eg assuming demand is proportional to supply and that value for existing users does not change with total supply), using the same value for new and existing users, and the transfer of values from single sites elsewhere.

The question of whether to use benefit transfer (as per Denne *et al* 2013) or not (as per Marsh and Mkwara 2013) is solved to a considerable extent by three more recent studies which provide more readily usable valuation data by analysing the WTP for water quality improvements of larger populations and over a wider area. These studies by Phillips (2014), Miller *et al* (2015) and particularly Tait *et al* (2016) are discussed below.

3.3 Review of Recent Studies

The three studies summarised below are based on surveys of relatively wide samples of the general public, including those who use a freshwater site, or a set of sites, in different ways, and those who do not visit freshwater sites but who might value quality improvements.

Non-market valuation is typically done by estimating the value of, for example, a swimming trip to a river (and potentially at different water quality levels) and then estimating the change in the number of trips which might result from an improvement in river quality. Three new studies, described below, survey a sample of the regional or national population and estimate the value that they place on water quality improvements that would increase the value and/or number of trips to specific sites, or that would be valued for its own sake.

The advantage of these studies is that that the results can be used to value quality improvements without having to estimate changes in activity levels. For example, for valuing swimmability the values include those expressed by people who currently swim, those that might swim if water quality improved and those that place a value on water quality improvement to swimmable levels without swimming themselves. Provided the surveys are representative of the population, this provides a useful basis for estimating values that would apply to people in all of these categories, assuming the proportion of swimmers and non-swimmers in the sample is the same as in the general population.

The studies apply to widespread national or regional improvements in water quality.

3.3.1 Phillips (2014)

Phillips (2014) analysed the impacts of setting freshwater objectives and limits in the Waikato River Catchment. The study included the results of:

- a revealed preference (RP) analysis using analysis of travel costs and trip counts to estimate preferences for different levels of water quality based on the range of existing quality levels; and

- a stated preference (SP) analysis using a choice experiment to estimate willingness to pay for water quality improvement. The SP study was based on a February 2014 survey of a wide population; it included respondents from Auckland, the Bay of Plenty and the Waikato region, all of whom might use the Waikato River for recreational purposes or value its water quality.

The results of the SP analysis are shown in Table 10, updated to 2019 dollar values. The values are for improvement from (or staying at) the lowest level of water quality. The results were separated into values expressed by people who had visited a river, stream, lake or wetland in the Waikato region (users) and those who had not (non-users).

Table 10 Value of water quality improvements in the Waikato ($per household per year)

Attribute	Level	User (2014$)	Non-user (2014$)	User (2019$)	Non-user (2019$)
Water Clarity	0.2	$3.98	$2.86	$4.27	$3.07
Visible metres (black disc)	0.6	$14.18	$10.19	$15.23	$10.94
	1.1	$31.12	$22.37	$33.42	$24.02
	1.6	$52.73	$37.90	$56.62	$40.70
	2.5	$103.36	$74.29	$110.99	$79.77
	3.5	$177.33	$127.45	$190.41	$136.85
Infections	1	$172.94	$124.30	$185.70	$133.47
(number of people who will get sick per 1,000 swimmers)	10	$152.72	$109.77	$163.99	$117.87
	50	$88.25	$63.43	$94.76	$68.11
	100	$19.55	$14.05	$20.99	$15.09
	300	$2.00	$1.44	$2.15	$1.55
Ecosystem health	Poor	$56.90	$40.89	$61.10	$43.91
(level of nutrients & algae + suitability for sensitive species)	Fair	$155.35	$111.65	$166.81	$119.89
	Good	$182.30	$131.02	$195.75	$140.69

Note: All values inflated to Q4 2019 from Q1 2014 values (survey in February 2014) using CPI: Statistics New Zealand, Infoshare Database: CPI Index All Groups for New Zealand: Q1 2014 = 972; Q4 2019 = 1044
Source: 2014 values from Phillips (2014)

The Phillips study is for a single river catchment, but the results (at least using the non-user values, which are a significant proportion of total benefits) are likely to be a minimum for the per household benefits of quality improvements across all freshwater bodies, as relevant to this current impact analysis. Tait *et al* (2016), who conducted a national study, suggest the Phillips (2014) values are consistent with their results (see below).

Phillips produced values for water clarity, reduced infections (from *E coli*) and ecosystem health.

Water Clarity

Water clarity is valued by those who use waterways for recreation and other direct uses, and as a general indicator of quality, eg as an element of existence value for non-users. The water clarity attribute is measured as the distance (in metres) that a dark object (a black disc) can be seen from. This is the same basis for values as used in other studies of the value of water clarity.[48] To make use of these values would require a projection of the impacts of proposed changes in water quality on water clarity, as Landcare did with the water clarity benefits from Tait *et al* (2016) (see Section 3.3.3). We discuss this in Section 3.4.

[48] See, for example, Marsh (2010) and Mkwara and Marsh (2011) in Marsh and Mkwara (2013)

Infections

The risk of infections is an indicator of how suitable the water body is for swimming, but this quality is also valued by non-users. The categories used (Table 10), risk of infections per 1,000 swimmers, can be related to the levels of *E coli* in the water, using categories developed by MfE[49] (see discussion in Section 3.4).

Ecosystem Health

The results for ecosystem health are based on broad categories that refer to levels of nutrients and algae and the suitability for sensitive species. The values (Table 10) were for an improvement over very poor health.[50]

3.3.2 Miller et al (2015)

Miller *et al* (2015) used a choice experiment of Canterbury residents in a 2012 survey which included environment, recreational and cultural attribute, plus an employment attribute (number of jobs that resulted from increased use of water for irrigation). The survey was aimed at the general public and sought to identify values for generalised improvements in water quality across the region as a whole. This would include the value for those who did and for those who did not visit the site for recreation.

The estimated values from the study are summarised in Table 11.

Table 11 Value of Canterbury river attributes ($per person per year)

Attribute	Level/ category	Median (2012$)	Range (2012)	Median (2019$)	Range (2019$)
Employment	1 new job	$0.16	$-0.08 - $1.32	$0.18	$-0.09 - $1.45
Environment (QMCI value)	poor to fair	-$11.78	$-25.43 - $48.31	-$12.90	$-27.84 - $52.89
	poor to good	$30.21	$1.61 - $152.89	$33.08	$1.76 - $167.4
	poor to excellent	$122.55	$22.82 - $597.35	$134.18	$24.99 - $654.04
Social/Recrea-tional (% of sites suitable for swimming)	20%	$23.69	$-6.12 - $155.46	$25.94	$-6.7 - $170.21
	40%	$29.53	$9.96 - $110.49	$32.33	$10.91 - $120.98
	60%	$35.88	$0.28 - $197.42	$39.29	$0.31 - $216.16
Cultural (abundance and range of *mahinga kai* available)	below average	$28.53	$-24.14 - $259.89	$31.24	$-26.43 - $284.55
	for Maori	$38.96	$-18.25 - $294.68	$42.66	$-19.98 - $322.65
	above average	$28.10	$-4.44 - $179.8	$30.77	$-4.86 - $196.86
	for Maori	$40.69	$1.39 - $215.45	$44.55	$1.52 - $235.9

Note: All values inflated to Q4 2019 from Q4 2012 values using CPI: Statistics New Zealand, Infoshare Database: CPI Index All Groups for New Zealand: Q4 2012 = 954; Q4 2019 = 1044
Source: 2012 values from Miller et al (2015)

Employment

Additional jobs and the value of employment (associated with irrigation-based agriculture) is traded off against improvements in water quality in the Miller *et al* (2015) study.[51] Additional employment is given a positive value by survey respondents.

Typically, employment (or labour) is treated as a cost in a CBA. This is based on the assumption that, all other things equal, people would prefer not to work and only do so if they are compensated with

[49] : NZ Government (2017); Ministry for the Environment (2017; 2018)
[50] Defined as “Very high levels of nutrients and algae. Unsuitable for sensitive species.”
[51] A similar approach is used by Marsh (2010).

wages. The level of wages reflects the opportunity cost of their labour as it is assumed to equal what they would be paid in some other productive activity. Including a positive value for employment is a community value, ie it is the value obtained by an individual for knowing there are more jobs in the community. Additional jobs are valued, presumably, because they would be expected to result in spillover effects reflecting a more vibrant local economy with more consumption opportunities, but there may also be altruistic reasons.

Environment

Miller's environment category is measured using the quantified MCI (QMCI). It is a measure of stream "health", calculated from the presence of types of invertebrate expected in water of different levels of quality (Box 1). The authors note a significant finding was that Māori have approximately 40 percent higher WTP for environmental quality improvements than the general population.

Social/Recreational

Suitability of sites for swimming was used as a recreational attribute. Miller et al use the percentage of popular sites in the region being suitable for swimming, ie that meet a safe swimming threshold based on an Environment Canterbury "Suitability for Recreation Grade assessment".[52] Because the measurement is based on the proportion of popular sites, these values are less easily transferred for use with a more generalised increase in quality and where information on popularity is not readily available.

Cultural

Miller *et al* (2015) include a cultural value in the form of availability of *mahinga kai*.[53] This was based on the Cultural Health Index (CHI) developed with input from Māori communities.[54] Miller *et al* note that CHI takes account of species availability, ongoing abilities to harvest and access the sites, and perceptions of site use. Use of this attribute requires analysis at a level of disaggregation not possible in this current study.

3.3.3 Tait et al (2016)

Tait *et al* (2016) undertook a national survey of a representative sample of people to examine the benefits of a policy to exclude farm animals from waterways. The results are shown in Table 3 above (Section 2.2) as the benefits of a "percentage point increase in the proportion of waterbodies that achieve a particular water quality outcome." It provides an excellent basis for the analysis required in this study because the results are based on a national survey of the general public.

Tait *et* al (2016) provide the most recent set of data and in a format that is highly suitable for this study.

The different attributes are discussed briefly below.

Human health risk

Human health risk was measured as the number of people who have contact with a waterway and then become sick. They adopted the health risk categories used in the National Objectives Framework National Policy Statement for Freshwater Management (see Table 5).

[52] See Environment Canterbury (2016)
[53] These are indigenous species that have traditionally been used for food, tools, or other resources – see https://niwa.co.nz/our-science/freshwater/tools/kaitiaki_tools/species
[54] Tipa and Teirney (2003)

Ecological quality

Ecological quality was measured using MCI scores (Box 1), based on the presence (or absence) of different kinds of indicator species.

Water clarity

Water clarity is measured using the black disc method (as with Philips 2014).

3.3.4 Comparison of Values

Tait *et* al (2016) suggest their results are consistent with those obtained by Miller *et al* (2015) and Phillips (2014). For example, they estimate a WTP of \$0.60 per 1% increase in the number of monitored sites suitable for swimming (\$35.88/60 = \$0.60) from Miller *et al*, compared to \$1.15 in a range of \$0.65 to \$1.65 for the 1:100 human health risk category (the relevant level for Miller *et al*'s study). Tait *et al* (2016) suggest their values are higher because of the difference in scale between regional and national outcomes employed across the studies

If we compare the numbers to those of Phillips (2014), she suggests an average non-user benefit of \$4.11 (and a user benefit of \$5.72) for a 1% improvement in number of sites suitable for swimming (in 2014\$ values), ie:

$$\frac{\$124.30 - \$1.44}{\left(\frac{300}{1000} - \frac{1}{1000}\right) \times 100} = \$4.11$$

The value is even higher (\$16 per 1% improvement) if examining the marginal improvement from 10/1000 to 1/1000 risk of an infection).

3.3.5 Decreasing or Increasing Marginal Benefits

Tait *et al* (2016) show increasing marginal benefits of water quality improvement, ie as water quality improves there is a greater benefit from further improvements in quality.

Miller *et al* (2015) similarly find increasing marginal benefits of water quality improvements measured as QMCI, but find their swimming results suggest a a declining marginal benefit: the average value of improving sites such that 20% are suitable for swimming is \$1.28 per 1% improvement, but the average value of increasing the number from 40% to 60% of sites is only \$0.34 per 1% improvement.

Phillips (2014) finds increasing marginal benefits of both reducing infection risk and of increasing water clarity.

3.4 Quantification of Quality Improvements

In this section we bring together the analysis of the benefits of the individual components of the EF package to quantify the benefits of improvements in human health, water clarity and ecological health.

It has not been possible to estimate the benefits of the N and P Bottom Lines. To value these improvements requires that changes in N & P concentrations can be used to estimate changes in factors that are valued by people. An analysis of the 2013-17 monitoring data held by MfE suggests that there is a significant relationship between concentrations of N and P with both MCI and water clarity, but that there are many other factors affecting these outcomes such that we are unable to predict the effects from the limited data available (see Annex B). We have therefore not placed a monetary benefit value on the N & P bottom lines, despite the fact that they will lead to improvements in several valued outcomes. That said, some of these will be measured through the benefits estimated of other policies, including the MCI bottom lines which aim to improve ecosystem health. We analyse the benefits of these improvements in Section 0 below.

3.4.1 Human Health

For the human health benefits, we analyse the effects of the stock exclusion policy on *E coli* contamination of waterways, which reduces the probability of infection when swimming.

The WTP values derive from a national survey, as discussed in Section 2.2. It obtained values from the general population for improvements in the swimmability of rivers which they may or may not visit. The values are for percentage improvements in the number of streams falling into different risk categories (1:1,000, 1:100 and 1:20), representing the risk of getting sick if swimming.

Using risk categories from the Draft National Policy Statement for Freshwater Management (Table 12), NIWA analysed the impacts of the stock exclusion policy on the length of streams under different categories. In Table 13 we show the results for one of the scenarios (Scenario 3b) and the baseline; Scenario 3b is regarded by MfE as being closest to the policy proposals. The risk categories can be associated with those used by Tait *et al* (2016) to estimate the monetary value of the water quality improvements relating to human health.

Table 12 Risk categories

Band	Average risk	Assume	1 in:	Tait categories
A	1%	1%	100	1:100
B	2%	2%	50	1:20
C	3%	3%	33	1:20
D	>3%	5%	20	1:20
E	>7%	10%	10	>1:20

Note: The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place.
Source: Risk bands and average risk from Ministry for the Environment (2019e)

Table 13 Stream length under different risk categories

	A	B	C	D	E
Baseline	107.2	92.4	50.5	83.4	66.5
Scenario 3b	135.9	102.6	65	70.5	26.1
Change	28.7	10.2	14.5	-12.9	-40.4

Source: Semadeni-Davies et al (2020)

The percentage point improvements are shown in Table 14, along with the corresponding estimates of value (median, low and high). Unlike the original study, which used percentage change in the number of streams in the different categories, this uses percentage change in stream length. We use this as a proxy for percentage improvement in number of streams (or assume that people will value this improvement equally).

Table 14 Average impacts per person of improvements in swimmability

Band	% improvement	% points	Median Value (range)	Total – Median value ($/person)	Low ($/person)	High ($/person)
1:100	27%	26.8	$1.22 ($0.69 - $1.75)	$32.73	$18.47	$46.85
1:20	5%	5.2	$0.74 ($0.23 - $1.36)	$3.88	$1.20	$7.09
Total				$36.61	$19.67	$53.94

The value per person in Table 14 needs to be aggregated to a national level using the adult (18+) population. We use StatisticsNZ population projections[55] to estimate current and future values; consistent with Tait *et al* (2016), these are multiplied by 0.79 to account for the proportion of people (0.21) who stated a zero WTP for water quality improvements. The adjusted numbers are combined with an estimate of the rate at which the stock exclusion policy is introduced (see Section 1.6) and combined with the value per person.

Table 15 shows the estimated benefits in years 2030, 2040 and 2050 (undiscounted) and Table 16 shows the present value of benefits from 2020 to 2050; they are estimated at $2.4 billion (in the range of $1.3 to 3.5 billion) at a 3% discount rate.

Table 15 Estimated annual values of human health benefits ($ million)

Year	Median value	Low	High
2030	$124.1	$66.7	$182.8
2040	$133.7	$71.9	$197.1
2050	$137.7	$74.0	$202.8

Note: Low and High values are based on the 5th and 95th percentile values from Tait et al (see Table 3)

Table 16 Estimated present value (to 2050) of human health benefits at different discount rates ($ million)

	0%	1%	3%	6%
Median	$3,732	$3,180	$2,366	$1,609
Low	$2,006	$1,709	$1,272	$865
High	$5,499	$4,685	$3,487	$2,371

3.4.2 Water Clarity

The stock exclusion policy is estimated to have an impact on water clarity, in addition to human health benefits. To examine these benefits we use the values from Tait *et al* (2016), scaled to current dollar values (see Table 3 on p10) and to the national level based on the adult (18+) population multiplied by 0.79 (as with the human health analysis) to take account of those with a zero WTP.[56] To derive a present value of future benefits, we use the assumptions on implementation rates as discussed in Section 1.6

There are also expected to be water clarity benefits from sediment bottom lines, as examined by Landcare (see Section 2.4). However, MfE suggests these benefits (and the associated costs) cannot be unambiguously attributed to the sediment policy because climate policy, consistent with the Climate Change Response (Zero Carbon) Amendment Act 2019, is likely to produce many of the same outcomes, particularly because of the scale of associated afforestation. Nevertheless, for

[55] NZ.Stat Subnational population projections, by age and sex, 2013(base)-2043 update
[56] This is the factor identified and used by Tait *et al* (2016)

completeness we include the analysis here. The assumptions used in our analysis are different from those adopted by Landcare, as discussed in Section 2.4.

Stock Exclusion

The impacts of stock exclusion policy on water clarity was estimated by NIWA. They estimated how in-stream sediment reductions associated with stock exclusion Scenario 3b will affect water clarity across the national river network. Specific outputs were estimates of:

- the percent of the river network that meets the water clarity bottom lines,[57] nationally and by region, before and after the stock exclusion proposals are implemented; and
- the percent of the river network in poor (clarity < 1.2 m), moderate (clarity 1.2 – 2.4 m) and good (clarity > 2.4 m) state before and after stock exclusion proposals are implemented.

The outputs are reproduced in Table 17, and are consistent with Tables 20 and 21 in Neverman *et al* (2019) (See Table 8 above).

Table 17 Impacts of Stock Exclusion Policy on Water Clarity Outcomes

Region	% compliance before mitigation	% compliance after mitigation	% point improvement	% Good	% Moderate	% Poor
Auckland	87.07	87.64	0.57	0	4.7	95.31
Bay of Plenty	97.83	97.92	0.09	0	96.3	3.7
Canterbury	93.03	95.65	2.62	0	99.96	0.04
Gisborne	94.4	94.42	0.02	0	100	0
Hawke's Bay	96.47	97.47	1	0	99.71	0.29
Manawatu Whanganui	76.16	77.63	1.47	0	67.93	32.07
Marlborough	97.14	97.23	0.09	0	100	0
Northland	87.83	90.69	2.86	0	23.91	76.09
Otago	81.96	83.9	1.94	0	72.06	27.94
Southland	74.4	77.44	3.04	0	37.05	62.95
Taranaki	94.95	96.71	1.76	0	0	0
Tasman/Nelson	99.33	99.38	0.05	0	70.89	29.11
Waikato	64.39	66.81	2.42	0	100	0
Wellington	89.64	90.01	0.37	0	40.11	59.89
West Coast	95.24	95.46	0.22	0	91.43	8.57
NZ	86.2	87.81	1.61			

Source: Hicks (2020)

The first two columns show percentages of river network segments meeting the clarity bottom lines before and after stock exclusion, with the third column showing the difference as a percentage point improvement. The final three columns show the percentage of segments that are predicted to meet the bottom lines in terms of their starting levels of water clarity, ie in Auckland 4.7% of those that will change to meeting the bottom lines after the policy is introduced are starting from a position of moderate water clarity and 95.3% are starting from poor water clarity. To estimate the benefits of improvements we use an equation of the following form:

$$V_{WC} = P \times Z \times PPI \times PSS \times WTP$$

[57] Assessed by Hicks and Shankar (2020)

Where: V_{WC} = value of water clarity improvement

P = Adult population in the region or NZ

Z = Proportion of population with a zero WTP, ie 0.79

PPI = Percentage point improvement in segments that are compliant

PSS = Percentage of segments moving to compliance by starting state

WTP = willingness to pay for 1% improvement by starting condition

The results are shown in Table 18 (annual values) and Table 19 (present value to 2050). AT a 3% discount rate the benefits to 2050 are estimated to total $221 million (in a range of $195 to $247 million)

Table 18 Estimated annual water clarity benefits of stock exclusion ($ million)

Year	Median value	Low	High
2030	$11.7	$10.3	$13.0
2040	$12.4	$10.9	$13.8
2050	$12.5	$11.0	$14.0

Note: Low and High values are based on the 5th and 95th percentile values from Tait et al (see Table 3)

Table 19 Estimated present value (to 2050) of water clarity benefits at different discount rates ($ million)

	0%	1%	3%	6%
Median	$347	$296	$221	$150
Low	$306	$261	$195	$133
High	$388	$331	$247	$168

Sediment Policy

Using the same methodology, we estimate the benefits of sediment policy using the data from Hicks *et al* (2019) and Neverman *et al* (2019) (Table 20).

Table 20 Impacts of Sediment Bottom Lines on Water Clarity Outcomes

Region	% compliance before mitigation	% compliance after mitigation	% point improvement	Good	Moderate	Poor
Auckland	88.4	89.2	0.8	1.1	97.9	1.1
Bay of Plenty	91.9	93.9	2	48.8	51.2	0
Canterbury	82.8	84.5	1.7	83.5	16.5	0
Gisborne	77	84.9	7.9	88	12	0
Hawke's Bay	91.3	93.5	2.2	65.9	34.1	0
Manawatu Whanganui	72.5	72.6	0.1	84.1	15.9	0
Marlborough	94.8	96.9	2.1	94.9	5.1	0
Northland	86.8	88.8	2	0.2	91.5	8.4
Otago	78.3	82.7	4.4	45.8	32.4	21.8
Southland	73.3	74.4	1.1	4.4	67.2	28.3
Taranaki	88.6	89.4	0.8	1.5	98.5	0
Tasman/Nelson	96.5	96.5	0	100	0	0
Waikato	63.2	73.4	10.2	9	44.7	46.4
Wellington	87.9	93.3	5.4	76.3	23.7	0
West Coast	91.4	91.5	0.1	39.1	60.9	0
NZ	86.2	87.81	1.61			

Source: Neverman *et al* (2020), Tables 20 and 21

The estimated results (Table 21 and Table 22) assume the policy is implemented independently of the stock exclusion policy. The numbers are not additive as stock exclusion would be expected to change the starting water clarity state of some of the segments that will also benefit from the sediment bottom lines. However, if simply combined, the median benefits might be as high as $591 million at a 3% discount rate ($221 million from stock exclusion policy and $370 million from sediment policy).

Table 21 Estimated annual water clarity benefits of sediment bottom lines ($ million)

Year	Median value	Low	High
2030	$15.0	$13.7	$16.3
2040	$30.6	$28.0	$33.3
2050	$46.1	$42.2	$50.1

Note: Low and High values are based on the 5th and 95th percentile values from Tait et al (see Table 3)

Table 22 Estimated present value (to 2050) of water clarity benefits of sediment bottom lines at different discount rates ($ million)

	0%	1%	3%	6%
Median	$678	$551	$370	$214
Low	$621	$504	$339	$196
High	$736	$598	$402	$232

However, it is also possible that much of the benefits of the sediment policy will be achieved via other policies, eg those addressing climate change. MfE suggests that there will be considerable overlap between the effects of the sediment policy and the response to the Climate Change Response (Zero Carbon) Amendment Act 2019, such that neither the costs nor the benefits may be as modelled. We therefore ignore the benefits from sediment policy in this analysis.

3.4.3 Ecosystem Health

River ecosystem health is estimated to improve as a consequence of a number of different policies, but we examine it here as the benefits of achieving the MCI bottom lines. These are compared with current monitoring data to estimate changes in the number of rivers that will improve to higher categories of ecosystem health. This can be combined with the Tait *et al* (2016) values to quantify the benefits.

The MCI score (see Box 1) is used to classify a waterbody into an MCI Class (A to D) (Table 23). A national bottom line is proposed at an MCI of 90, ie all waterbodies must be at least a fair level of water quality.

Table 23 MCI Classes

MCI Class	MCI
A Excellent	≥130
B Good	≥110 & <130
C Fair	≥90 & <110
D Poor	<90

Source: Stark and Maxted (2007)

The Tait *et al* values (Table 3) can be used to measure the value for each percentage point improvement of value from poor (MCI of ≤80) to moderate (81-99) or good (≥100) ecological quality.

Their classifications are different from those in Table 23. However, we assume that rivers that improve from Class D (poor) to C (fair) obtain the same benefit as moving from poor to moderate on Tait *et al*'s classification.

Table 24 shows the number of monitored rivers by region falling into the different MCI classes. The final column is the percentage increase in Class C rivers if all the poor (class D) rivers move to fair (class C). These percentage improvements can be multiplied by the WTP from Table 3; the median value is $2.27 per person. This is multiplied by the regional adult population and a factor of 0.79 to account for the proportion of people who had a WTP of zero.

We use an equation of the following form:

$$V_{EH} = P \times Z \times WTP \times PI_{mod}$$

Where: V_{EH} = value of ecological health improvement

P = Population in the region or NZ

Z = Proportion of population with a zero WTP, ie 0.79

WTP = willingness to pay for improvement from class D to C, assumed to be $2.27

PI_{mod} = Percentage of rivers improving from class D to C

For example, in Northland (population estimated at 134,112 in 2020), where there is a 5.26 percentage point improvement, the equation is as follows:

$$V_{EH} = 134{,}112 \times 0.79 \times \$2.27 \times 5.26$$

$$= \$1{,}265{,}806$$

Table 24 Number of Monitored Rivers by MCI Band

Region	A	B	C	D	Total	% improve-ment
Northland	3	12	3	1	19	5%
Auckland	3	2	13	21	39	54%
Waikato	15	27	17	16	75	21%
Bay of Plenty	8	38	19	9	74	12%
Gisborne	0	1	0	0	1	0%
Taranaki	12	9	32	6	59	10%
Manawatu-Wanganui	5	33	35	10	83	12%
Hawke's Bay	2	19	26	21	68	31%
Wellington	7	21	20	9	57	16%
Tasman	1	11	2	6	20	30%
Nelson	4	7	9	6	26	23%
Marlborough	0	15	9	2	26	8%
West Coast	3	23	11	1	38	3%
Canterbury	1	35	69	29	134	22%
Otago	0	10	21	10	41	24%
Southland	1	27	31	13	72	18%
Total	65	290	317	160	832	19%

Source: MfE

In practice, the MCI bottom lines will not be achieved immediately. Rather these benefits will phase in over time (Section 1.6); in addition, only some of the benefits might be attributed to the EFW rather than the NPS-FM; we assume that 50% is attributable to the EFW. Using these assumptions, we estimate the median, low and high benefits of MCI improvement in Table 25 (annual values in 2030, 2040 and 2050) and Table 26 (present value at different discount rates).

Table 25 Estimated annual ecosystem health benefits of MCI bottom lines ($ million)

Year	Median value	Low	High
2030	$25.0	$20.3	$29.7
2040	$52.1	$42.2	$61.9
2050	$79.4	$64.2	$94.3

Note: Low and High values are based on the 5th and 95th percentile values from Tait et al (see Table 3)

Table 26 Estimated present value (to 2050) of ecosystem health benefits of MCI bottom lines at different discount rates ($ million)

	0%	1%	3%	6%
Median	$1,234	$996	$661	$375
Low	$998	$805	$535	$304
High	$1,465	$1,182	$785	$445

3.5 Ecosystem Services

As noted in Section 1.5, the ecological status of freshwater systems can have effects that go well beyond those that are readily identified or which happen directly. This makes these effects difficult to identify; they are also not well studied or understood. Writing in 2013, Joy and Death, for example, suggest that the role of biodiversity in the functioning of running-water ecosystems and the relationship with environmental stress has had little attention by researchers in New Zealand.

Schallenberg *et al* (2013) discuss the role of lakes in the assimilation and sequestration of nutrients and contaminants, which improves water quality and habitats. But they suggest these services are vulnerable to excessive nutrient loading rates and to invasive species. Table 27 shows their estimates for one lake of the differences in services provided under different quality states.

Table 27 Ecosystem services identified for Lake Ōmāpere under different states

Ecosystem service	Desired state	*Egeria* dominated	Algal dominated
Provisioning	•Domestic and rural water supply •Sustainable commercial tuna fishing •Sustainable customary tuna harvesting •Shellfish gathering •Swan shooting •Natural fibres •Recreation	•Domestic and rural water supply •Commercial tuna fishing •Restricted customary tuna harvesting •Shellfish gathering •Swan shooting •Natural fibres	•Rāhui (ban) on commercial tuna fishing •Restricted customary tuna harvesting •Restrictions on shellfish harvest in Hokianga harbour
Supporting & regulating	•Water filtering (torewai & plants) •Nutrient lock-up (sediments/plants) •Denitrification •Drainage •Water storage •Flood buffering •Native biodiversity & rare species (mudfish, *Isoetes*, longfin)	•Water filtering (torewai & plants) •Nutrient lock-up (sediments/plants) •Denitrification •Drainage •Reduced water storage (weed-beds) •Flood buffering •Reduced native biodiversity & rare species (mudfish, longfin)	•Denitrification •Drainage •Water storage •Flood buffering •Reduced native biodiversity & rare species (mudfish, longfin)
Cultural[1]	•Kaitiakitanga actively practiced by manawhenua •Spiritual wellbeing (e.g. sites of importance for spiritual practise protected and enhanced) •Preservation of cultural heritage/landscapes and practise of whakapapa, taonga and mātauranga related activities (e.g. intergenerational knowledge transfer occurring) •Cultural events and activities •Eco-tourism	•Kaitiakitanga actively practiced by manawhenua •Reduced spiritual well being •Impacted intergenerational knowledge transfer opportunities	•Kaitiakitanga actively practiced by manawhenua •Reduced spiritual well being •Impacted intergenerational knowledge transfer opportunities

Source: Schallenberg *et al* (2013)

These and other studies illustrate the complex relationships between freshwater and the things that people value. We are unable to value these relationships in monetary terms, particularly the impacts of marginal changes in quality as a results of the additional policy effort (from NPS-FM to EFW package).

4 Commercial and Reputational Values

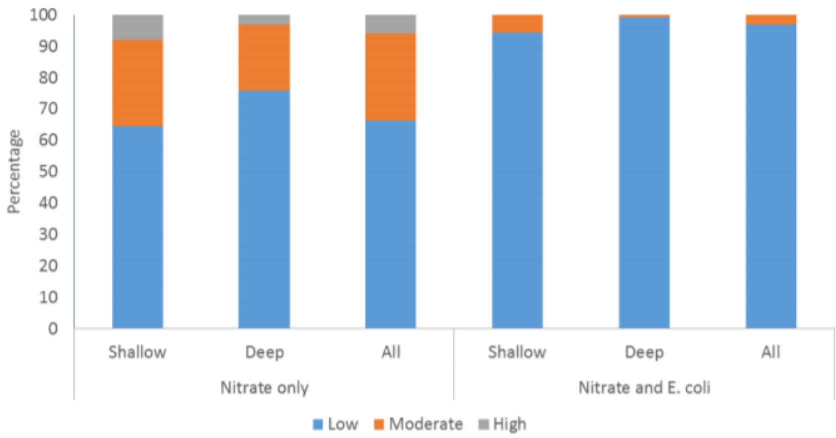
In this section we examine data that might be used to estimate the market impacts of changes in water quality. We consider:

- Avoided costs of denitrification of drinking water
- The economic value of commercial activities using freshwater; and
- The value of clean water to New Zealand's environmental reputation and any associated price premium in export markets.

4.1 Drinking Water Contamination

The contamination of drinking water with nitrates from discharges of nitrogen presents risks for human health, particularly for infants,[58] and including bowel cancer risks for adults.[59] In New Zealand, particular concerns have been raised over nitrate concentrations in groundwater in Canterbury (Figure 7) and Waikato (Figure 8) regions, where the risk categories below have been defined on the basis of risks of infant methaemoglobinaemia (or blue baby syndrome)[60] building on WHO guidelines.[61]

Figure 7 Percentage of Sites in Risk Categories: Canterbury

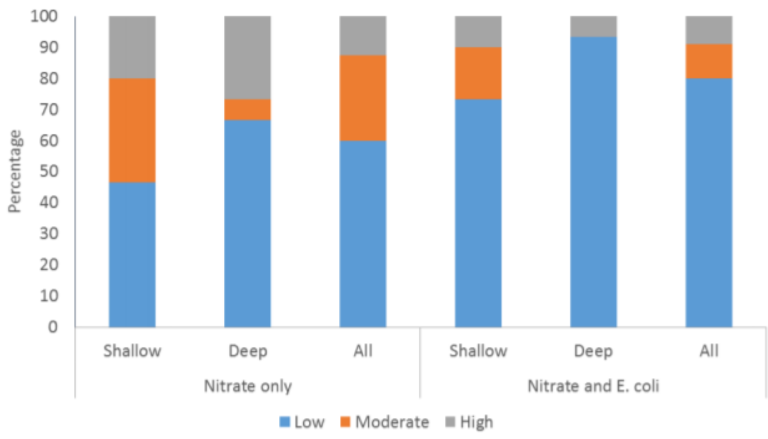


Source: Cooke and Phillips (2014)

Reducing levels of discharge to land is expected to reduce nitrate levels in groundwater, although there may be significant delay because of the time taken for nutrients to move through the soil. The benefits of reducing discharges are either in the form of improved health outcomes or reduced costs from (1) avoided development of new water supplies, (2) nitrate removal, eg via ion exchange,[62] or (3) dilution of contaminated supplies with water from other supplies.[63] Costs of nitrate treatment have been estimated for the US, with costs varying significantly with system size;[64] an example is shown in Table 28 showing lifetime costs (capital and operating) for household and community (c.10,000 people) systems in 2010 US dollars, converted to 2020 NZ dollar values.

58 World Health Organization (2011)
59 Schullehner et al (2018)
60 Exposure to high nitrate levels in drinking water may prevent the blood from delivering oxygen effectively in the body: Canterbury District Health Board (2016)
61 World Health Organization (2011)
62 Ministry of Health (2007)
63 CH2M Beca Limited (2010); Jensen et al (2012)
64 Jensen et al (2012)

Figure 8 Percentage of Sites in Risk Categories: Waikato



Source: Cooke and Phillips (2014)

Table 28 Lifetime costs (2010US$ and 2020NZ$) of denitrification options

Method	Household (US$/hh)	Community (US$m/cs)	Household (NZ$/hh)	Community (NZ$m/cs)
Reverse osmosis	$1701 - $5543	$44 m	$2739 - $8924	$71m
Distillation	$5759 - $8505		$9272 - $13693	
Ion exchange	$4025 - $8283	$9.2 m	$6480 - $13335	$15m
New well	$7200 - $16000		$11592 - $25759	
Bottled water	$7506 - $23717		$12084 - $38183	
Biological denitrification		$6.2 m	$2739 - $8924	$71m

Notes: cs = community system; converted from US2010$ to 2020NZ$ using US PPI (2010 to 2020)[65] and 2020 US:NZ exchange rate (0.6434 average)[66]
Source: US cost estimates from Juntakut *et al* (2020)

We have not quantified potential cost saving benefits as part of this study, because of the considerable uncertainties over the relationship between discharge reduction and groundwater concentrations.

4.2 Value of NZ Fisheries

Our interest in this report is in the benefits that freshwater provides and the changes in the benefit values because of changes in water quality. Available data on levels of use of freshwater for recreation are discussed in Annex A. The numbers are uncertain but more importantly there are few studies which estimate possible changes in activity levels in response to changes in water quality.

Bell and Yap (2004) conducted a survey which included an assessment of the effect of reduced numbers of algal blooms on a wide range of recreational activities. If algal blooms were eliminated, they estimated a 650% increase in recreational activity (days spent swimming, boating, fishing and so on) at Lake Rotorua and a 237% increase in the rest of the Bay of Plenty. Phillips (2014) estimates 12% increases in the number of visits to the Waikato river following improvements in water quality

[65] US Bureau of Labor Statistics PPI (2010 = 189.7; 2020 = 196.5)
[66] Reserve Bank

but, significantly, she also estimates corresponding decreases in visit numbers to other freshwater sites, especially Lakes Taupo, Rotoroa (in Hamilton) and Karapiro. The potential for shifting between sites cannot be limited to freshwater sites, with the potential also for shifting to other forms of recreation.[67]

For recreational use the value of interest to this study is the surplus that people obtain when they pursue freshwater-based activities. This surplus is measured as the difference between what they spend and their WTP; it assumes this is the retained value in the community, on the assumption that the costs of recreation are real resource costs. By real resource costs we mean that the prices paid (for equipment, fishing licences, travel costs and so on) are equal to the opportunity costs of their provision. So, if there is no surplus (WTP = amount paid), there is no net community value from the activity. This is the basis for the benefits evaluated explored using the Tait *et al* (2016) results in Section 3.

A study of the value of Otago sports fisheries estimated the consumer surplus to be in the range of $64–$189 million per annum.[68] The study was based on a travel cost method, which used an angler survey to estimate travel costs and, by constructing a demand curve for fishing, derived a consumer surplus. However, this is not an estimate of the change in value from an improvement in water quality (as per Tait *et al*, 2016). It does provide a maximum estimate of value at risk, but that is on the basis of there being no substitute sites or substitute activities.

Some studies have been conducted on the expenditure of recreational activities. These are relevant to estimates of the GDP contributions of these activities, but they are not measures of community value (or wellbeing) because they do not value the consumer surplus obtained (if any). They are a measure of the demand for these activities. Below we provide a discussion of some of these data using values and text provided by the Department of Conservation (DoC) using information supplied by the New Zealand Fish and Game Council and/or the New Zealand Professional Fishing Guides Association.

Freshwater sports fishing licence sales nationally amount to $9.847 million per year (146,000 licences sold),[69] but far greater amounts are spent on outdoor equipment (including fishing gear, boats and vehicles), travel, accommodation, and other services associated with the recreational fishery.

The total GDP contribution of the sports fishery to the country as a whole is not currently known. However, the Taupō fishery[70] was estimated in 2013 to create at least $29 million per year in business turnover, adds $11 million to the size of the Taupō economy, and sustains nearly 300 jobs.[71] A 2016 Otago University study found that angling tourists spent roughly twice as much as the average visitor and contribute approximately $28 million per annum to the NZ economy.[72]

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[67] Scarpa (2003) discusses this issue with respect to woodland recreation
[68] Jiang (2014)
[69] Combined Fish & Game and DOC Taupō fishing licence sales data for 2016/17 (Michael Gee, DoC, pers comm).
[70] Taupō fishery represents 24% of nationwide licence sales (2016/17 sales data) and 10% of fishing effort (Unwin, 2016).
[71] DoC (2013)
[72] Hayes and Lovelock (2016)

Commercial use of freshwater provides significant incomes in some locations in New Zealand. At least some of this is at risk from the deterioration of water quality and is protected (or enabled to increase) from improvements in water quality.

4.3 Reputational Value

Surveys have suggested the international perception of New Zealand's natural environment is important to the value of exports,[73] ie there is a price premium attached to the 'clean and green' image. MfE has previously estimated a value for this image of several hundred million dollars and that loss of the premium would be very difficult to reverse.[74]

Concerns have been raised that this image is at stake, particularly because of the impacts of the dairy industry on water quality.[75] In this analysis, even if the image could be valued, our interest is in the marginal value of the image, ie the change in image value if the quality of the environment changed.

A recent study by Lincoln University examined the WTP for attributes of food by consumers for different products and in different markets.[76] The research focussed on "credence attributes", including those relating to food safety, animal welfare, environmental outcomes, country-of-origin, functional (or healthy) foods and the use of organic production methods. They report the results of surveys using choice experiments, on the price premium people in different markets would be willing to pay for food that is certified by these attributes. Table 29 shows the WTP a price premium of different levels for lamb purchased, by consumers in China, India and the UK. For minimised water pollution, the median WTP is 7% in China, 21% in India and 6% in the UK. However, these are not values for reducing water pollution in New Zealand. The studies identified the WTP for credence attributes independently of any WTP for New Zealand as a country of origin,[77] so the WTP may be for water quality improvement in the country of the consumer.

Table 29 Median willingness to pay (% increase in product price) for lamb under different certifications

WTP for lamb production officially certified:	**China**	**India**	**UK**
as safe to eat	34%	49%	15%
to meet at least minimum animal welfare standards	9%	29%	18%
to minimise water pollution	7%	21%	6%
to minimise greenhouse gases	8%	28%	6%
to protect biodiversity	5%	26%	4%

Source: Tait *et al* (2020)

Table 30 shows the price premium consumers are willing to pay for reduced water pollution, for different products. Additional analysis was undertaken on the WTP for products sourced from New Zealand. However, this did not separate out the attributes of New Zealand that contributed to that WTP.

[73] Stewart (2012)
[74] MfE (2001)
[75] Foote (2014); Kaefer (2014)
[76] Tait *et al* (2020)
[77] See Saunders *et al* (2013) and Tait *et al* (2016)

Table 30 Median willingness to pay (% increase in product price) for reduced water pollution

Product	Attribute	China	India	UK
Lamb	Minimise water pollution	7%	21%	6%
Lamb	Water quality protection			0.5 – 0.7%
Dairy products	Minimise water pollution	16%	19%	3%
Kiwifruit	Water use & pollution minimisation	45%		

Source: Tait *et al* (2020)

Price premiums were identified for New Zealand produced products by consumers in California (36).

Table 31 Median WTP (% increase in product price) by Californian consumers for NZ-produced products

Product	WTP
Ground beef (mince)	20-22%
Sirloin steak	9-10%
Ribeye steak	10-11%
Sauvignon Blank wine	45%

Source: Tait *et al* (2018a); Tait *et al* (2018b)

From these studies we can conclude that:

- there is a value in New Zealand's international image that results in a price premium for some products;

- there is market value in cleaner water, associated with the production of some products also.

However, it is not possible to identify empirically the impact of a change in water quality in New Zealand on the price premium consumers would be willing to pay in other countries for products from New Zealand. However, there is significant value at risk.

5 Avoided Costs of Delay

Delays in implementing measures to address water quality have implications for the timing and the level of benefits, depending on the reversibility of damages. The timing effects are also further complicated by lag effects, ie the time delay between discharges of pollutants to land and when they flow into a waterbody. We explore these issues below, building off a report undertaken for MfE by NIWA which addresses these issues specifically.[78]

5.1 Cumulative Effects and Irreversibilities

Several factors within a waterbody mean that stopping or reducing inputs of nutrients or other pollutants will not result in an immediate improvement in water quality.

Rivers

- Nutrients are stored in sediments and in the aquatic biota. Release of nutrients from these sources will continue after the discharges stop. This applies particularly to lakes and poorly-flushed estuaries, but also can apply to rivers.

- Increases in the number and volume aquatic plants because of increased nutrients can lead to further retention and accumulatio of sediments.

- Increased nutrient concentrations can affect food for aquatic species leading to changes in community composition. These changes can be difficult to reverse when species more tolerant to degradation establish, even when conditions revers.

- For rivers, the frequency of flushing, eg by extreme hydrological events, will affect the extent of accumulation of sediments and biomass. Poorly-flushed systems will have more delayed responses to reduced inputs.

Estuaries

The extent of delays or irreversibilities can be more pronounced in estuaries because of the greater accumulation of sediment, including by significant growth of seaweed. However, the effects will depend on the frequency and extent of flushing, including by seawater and river flows.

As with rivers, the effects include changes in community structure and losses of species such as seagrasses, cockles and pipis.

Lakes

Lake sediments store large quantities of 'legacy' nutrients and organic matter. The extent of flushing depends on the lake's 'residence time', which is affected by rates of flows in and out in proportion to lake volume.

Lakes can switch between macrophyte- and phytoplankton-dominated states. When dominated by macrophytes (aquatic plants), the water quality is better and the water is more transparent, because the plants stabilize the sediment and reduce resuspension. The macrophytes rely on water transparency to photosynthesise but nutrient loading drives phytoplankton growth, reducing

[78] Graham *et al* (2020)

transparency. This is difficult to reverse. Climate change and higher associated lake temperatures is further driving this change, even without higher nutrient loading.

5.2 Lag Effects

In some soil types, and where there are groundwater reserves, there can be significant lags between the time that nutrients are discharged to soil and when they flow into a waterway. in the Lake Rotorua catchment, groundwater lags range from 14 to 170 years.[79] In contrast, in the Aparima catchment in Southland, lag times are estimated to be less than a decade.[80] Journeaux *et al* (2011) suggest that "a farm alongside the Waikato River may have a lag of only 1–3 years, whereas a farm at the top of the catchment may have a lag period of 50–60 years, and the overall mean lag period for the catchment may be (say) 30 years." For their analysis of the Waikato, they assumed a mean lag period for nitrogen leached from dairy farms of 15 years, with the proportion increasing over time, eg a reduction of 1 unit of N via leaching may see a reduction of 0.001 unit in groundwater flows into the river in year one, 0.002 in year 2, etc.

The systems studied in New Zealand tend to be those with long lags, but there is no systematic understanding of the extent of lags across New Zealand as whole. But the implications are that the consequences of current levels of nutrient discharge may not be known for some time and they will be effectively unavoidable until these systems are fully discharged.

[79] Rutherford *et al* (2019)
[80] Graham et al (2020)

6 Conclusions

6.1 The Benefits of the EF Package

The Essential Freshwater package is expected to have wide ranging benefits as summarised in Table 32.

Table 32 Benefits of the Essential Freshwater Package

Benefit Category	Value	Median Monetary value (and range)*	
Monetarised Non-Market Values		Annual in 2050 ($m)	Present value to 2050 ($m)**
Human health	Reduced risk of infection for swimmers Valued also by non-users.	$138 ($74-$203)	$2,366 ($1,272-$3,487)
Increased water clarity	Increased value of recreational use of water Valued also by non-users. Stock exclusion policy impacts counted only.	$13 ($11-$14)	$221 ($195-$247)
Ecological health	WTP for improved MCI score by users and non-users	$79 ($64-$94)	$661 ($535-$785)
Other Non-Market Values			
Water clarity and ecological health	Additional benefits from N & P bottom lines not quantifiable.		
Ecosystem services	Water quality is the basis for the functioning of other ecological systems that are the basis for other human values.		
Protection of financial values at risk			
Commercial value	Protection of the value of commercial angling (guided fishing) enterprises, in particular. Also, other water-based activities such as boat trips.		
Reputational value	Consumers in other countries are willing to pay a price premium for NZ products and for certified reduced water pollution. Some of this premium is at risk in the absence of improvements in water quality.		
Avoided costs			
Protection of drinking water quality in underground aquifers	Protection of human health for babies and adults, or avoided costs of denitrification		
Greenhouse gas reduction co-benefits	Water quality policy is expected to lead to increased afforestation and other planting. This will absorb CO_2 and reduce the need for other emission reductions to meet NZ's emissions cap.		
Avoided costs of delay			
Irreversible effects and higher future costs	Failure to reduce concentrations early can lead to the build up of sediments and contaminants in rivers, lakes and estuaries. This can result in shifts to alternative states which may be irreversible over reasonable time frames or high cost to change.		

* The range is based on the 5th and 95th percentile values in Tait et al (Table 3); ** The present value is to 2050 discounted at 3%

The values include:

- Monetarised non-market values based on the expressed willingness to pay of individuals for improvements in human health outcomes from water use, water clarity and ecosystem health.

- Improvements in additional non-market values that we have been unable to quantify, including ecosystem services.

- Protection of financial values at risk, including
    - commercial values from direct use of freshwater, eg guided fishing and commercialised boat trips;
    - the price premium that New Zealand exporters and tourism operators obtain on the basis of New Zealand's reputation for high environmental quality.

- Avoided financial costs, including costs of denitrification of drinking water and greenhouse gas reduction costs.

This study has also identified possible irreversible effects or those that are slow or costly to reverse. These include those associated with changes of ecological systems to alternative states. Reducing concentrations early helps to reduce the risks of these events.

The monetarised benefits are based on willingness to pay analyses which assume a set of existing rights to discharge contaminants. However, such rights are not established in law; rather the RMA states that no person may discharge any contaminant into water unless allowed by a regulation, a plan, or a resource consent. A different set of rights, eg which established rights for the public to have clean, uncontaminated water (unless appropriately compensated for any loss), could be agreed. It would require a different approach to valuation and would be expected to produce higher values than those presented here.

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9 Annex A Recreational Use of Freshwater

9.1 New Zealand Visitor Activity Forecast

There are no reliable data on levels of recreational activity at freshwater sites in New Zealand. The New Zealand Visitor Activity Forecast (NZVAF)[81] makes estimates of overnight stays and the related activities, some of which could be related to freshwater. However, in the absence of survey data it makes estimates of potential activity rather than actual activities, while noting that the actual activity levels are likely to be much lower than potential levels, particularly for NZ residents.

Table 33 summarises levels of potential activity in the NZVAF for rafting, canoeing, kayaking. Jetboating and fishing & hunting combined, all of which might be undertaken on freshwater.

- For domestic travellers (which are the larger contributors to the totals), the NZVAF uses the results of a survey of activity preferences (what activities respondents like doing), combined with the AA Traveller Monitor (AATM) which is a source of domestic travel data. The NZVAF assumes NZ residents undertake activities they have expressed a liking for in all places they stay overnight, eg those who have stated an interest in hunting and fishing are assumed to hunt and fish when they stay a night in Auckland (or anywhere else in New Zealand).

- For international visitors the activities are based on the International Visitor Survey (IVS) which asks visitors where they stayed and what activities they undertook in New Zealand (although not where they undertook them). They are assumed to undertake the activities they list as having done in all the places they stayed overnight.

Table 33 Potential freshwater visitor numbers (2020)

Potential activities	Domestic	International	Total
Rafting/canoeing/kayaking	4,018,200	368,200	4,386,400
Jetboating	3,672,400	393,500	4,065,900
Fishing/hunting	2,984,700	212,600	3,197,300
Total	10,675,300	974,300	11,649,600

[a] the number of adult visitors (15+ years) who stay overnight in the selected demand catchment and have a preference for the selected activity.
Source: New Zealand Visitor Activity Forecast, Fresh Information Co, https://freshinfo.shinyapps.io/NZVAF/

The implications of these assumptions are that these numbers are likely to be significant over-estimates of the number of overnight stays. Set against this, the NZVAF estimates do not include day trips, but only overnight stays.

9.2 National Angling Survey

There is an alternative data source for freshwater fishing activity. The National Angling Survey undertaken for Fish & Game estimates total “angling effort” for all New Zealand lake and river fisheries over a survey period. Angling effort is measured as angler-days, ie a day (or part day) spent fishing. The latest survey was for the 2014/15 angling season during which there were an estimated

[81] The NZVAF is developed by Fresh Information for New Zealand Trade and Enterprise (NZTE), Tourism New Zealand (TNZ) and the Ministry for Business Innovation and Employment (MBIE): https://freshinfo.shinyapps.io/NZVAF/

1.27 million angler-days, including locals and overnight visitors,[82] the same approximate number as in the 2007/08 survey.[83] These compare to an estimated 2.9 million hunting and fishing trips in 2018 in the NZVAF.

Assuming the same ratio (approximately 0.44) of actual (day and overnight) trips (from Fish & Game) to potential (overnight only) trips across the other activities (from the NZVAF) would suggest total visitor interactions with freshwater in 2020 of approximately 5 million, 8% of which are international visitors.

9.3 Trout Fishing

Trout fishing is an important recreational activity, dominated by the male population; they purchased 95% of adult whole season and family licences.[84] The angler survey showed that 10% of South Island adult male residents bought a whole-season fishing licence for the 2014/15 fishing season, with 18.5% and 17.3% respectively in Central South Island and Southland Fish and Game regions. Licence holding rates are lower in the North Island; approximately 1.5% of North Island adult male residents bought a whole-season fishing licence for the 2014/15 fishing season.

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[82] Unwin (2016)
[83] Unwin (2009)
[84] Female anglers were more significant purchasers of 24-hour licences (15% of total sales) and junior whole-season licences (13% of total sales). They accounted for 16% of whole-season licence sales in the Taupo Conservancy.

10 Annex B: Statistical Analysis of N & P

Below we show the results of an analysis of freshwater quality monitoring data (for 2013-2017). The analysis is of the relationship between concentrations of total nitrogen (TN), total phosphorus (TP) and with water quality outcomes: MCI score and water clarity.

10.1 Macroinvertebrate Community Index (MCI)

The factors affecting MCI include water depth and velocity, flow regime, algal biomass, sediment deposition and water quality. An increase of nutrient concentrations will cause an increase in the rate of growth of periphyton; an increase in periphyton will decrease MCI.

We show the relationship between MCI and total nitrogen (TN) and total phosphorus (TP) in Figure 9 and Figure 10 respectively. High levels of TN and TP are associated with low MCI, and high MCI is associated with generally lower TN and TP concentrations. However, there is a very wide spread of MCI values at low TN and TP concentrations, suggesting other factors are significant.

Figure 9 Relationship between total nitrogen concentration and Macroinvertebrate Community Index (MCI)

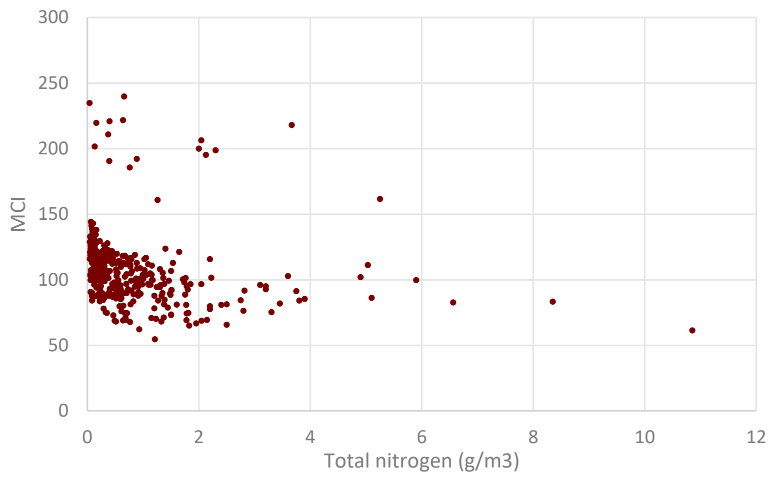
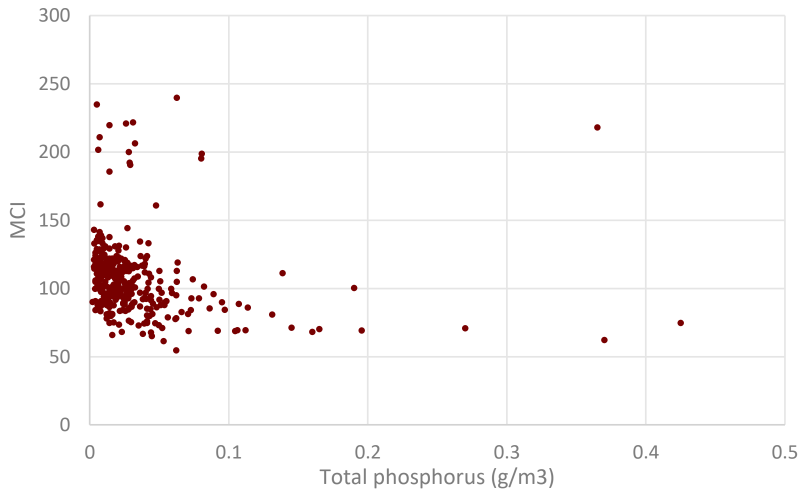


Figure 10 Relationship between total phosphorus concentration and Macroinvertebrate Community Index (MCI)



To test this, we try two predictive models using both TN and TP (in g/m^3). These are:

$$MCI = a.TN + b.TP + x \quad (1)$$

$$MCI = a.\log_e(TN) + b.\log_e(TP) + x \quad (2)$$

We also tested a log model using TN only. The results are shown in Table 34. None of the models are able to explain much of the variation in MCI suggesting that many other factors are important in determining MCI.

Table 34 Regression results - MCI

	Model 1	**Model 2**	**Model 3**
Predicted variable	MCI	MCI	MCI
TN	-63.66		
TP	-3.6**		
Log TN		-2.95	-6.76***
Log TP		-5.35***	
Constant	112.35***	91.64***	102.08***
N	348	348	348
R^2	0.04	0.08	0.07

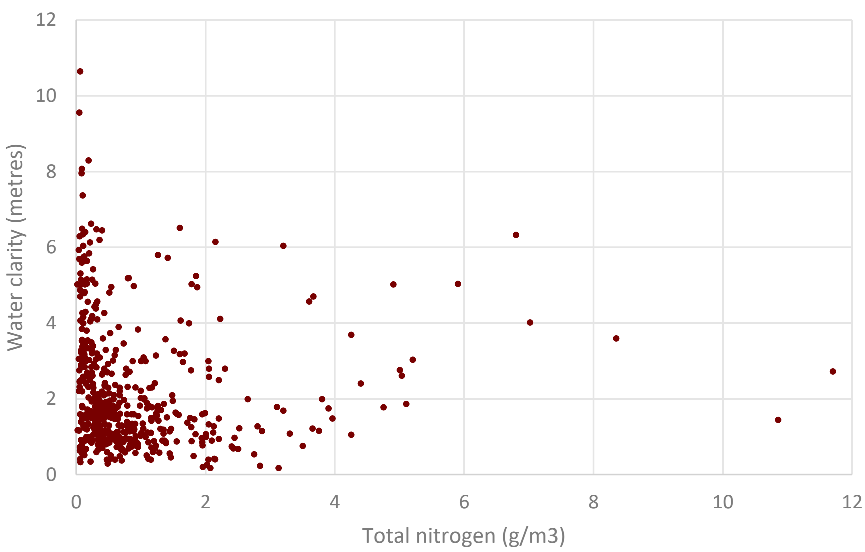
** = significant at the 1% level; *** = significant at the 0.1% level

10.2 Water Clarity

Water clarity depends on the concentration of particulate organic and inorganic material in the water column. The particulate matter comes from erosion of stream bed and banks, and catchment runoff, both of which vary with flow. The predictive data available to us for predicting changes in water clarity are limited to concentrations of nitrogen and phosphorus.

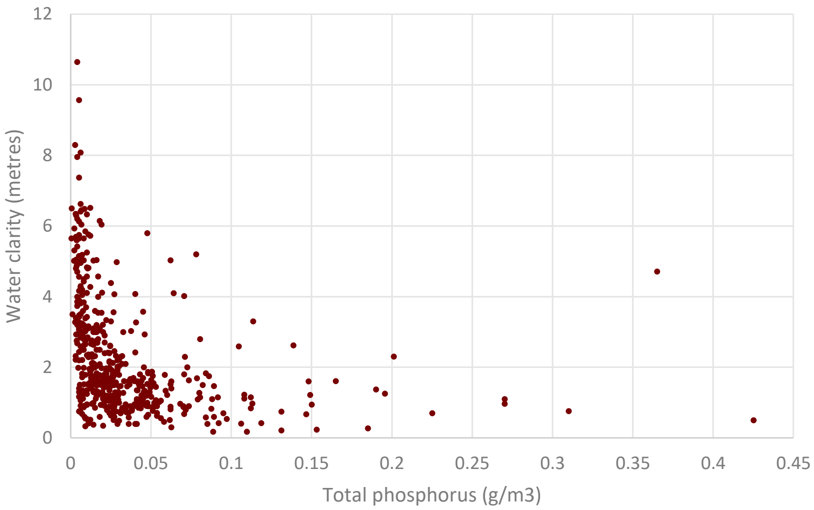
Using national monitoring data, Figure 11 shows the relationship between TN and water clarity and Figure 12 shows the relationship between TP and water clarity.

Figure 11 Relationship between total nitrogen concentration and water clarity



Source: analysis of MfE data – River water quality state 2013-2017.

Figure 12 Relationship between total phosphorus concentration and water clarity



Source: analysis of MfE data – River water quality state 2013-2017.

There is little obvious trend with the TN data, but there is with TP. High water clarity is only seen at low TP levels and, at high TP levels, water clarity is only low. However, there is a significant variation in the level of clarity at low levels of TP, suggesting that other factors are significant in explaining the clarity level.

This is confirmed by statistical analysis. Using a simple formula (3), the relationship between TN (in g/m^3) and water clarity is not significant ($p>0.2$) but it is for TP ($p<0.001$).

Water clarity (metres) = a.TN + x (3)
Water clarity (metres) = a.TP + x

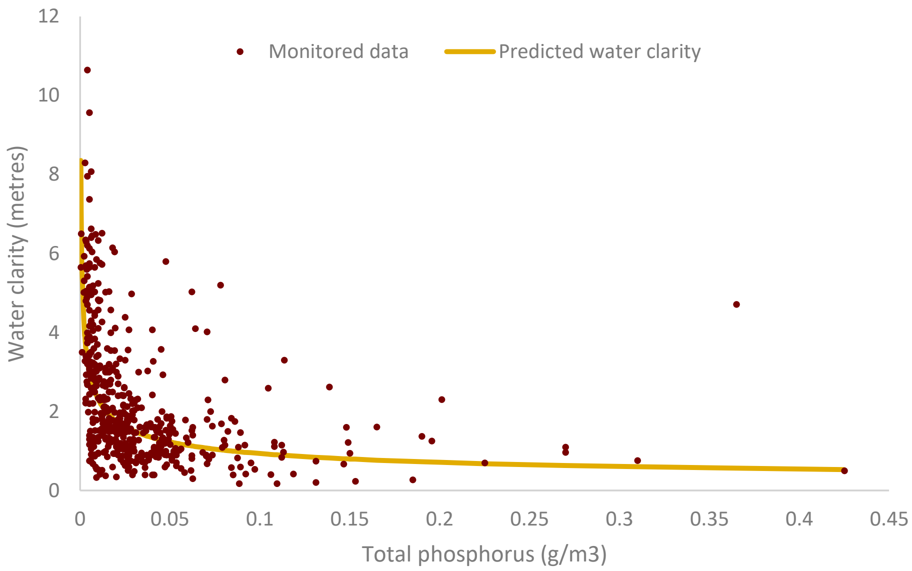
Where: a = a coefficient on TN or TP
X = a constant

We also try a log formula with TP (4).

Water clarity (metres) = a.$\log_e$(TP) + x (4)

The predicted relationship is shown in Figure 13. It is better able to explain the variation in water clarity (R^2 = 0.32) (Table 35), but is still not sufficient to be a useful predictive model; that would require more explanatory factors.

Figure 13 Relationship between total phosphorus concentration and water clarity – all NZ monitored data



Source: analysis of MfE data – River water quality state 2013-2017.

Table 35 Regression results - water clarity

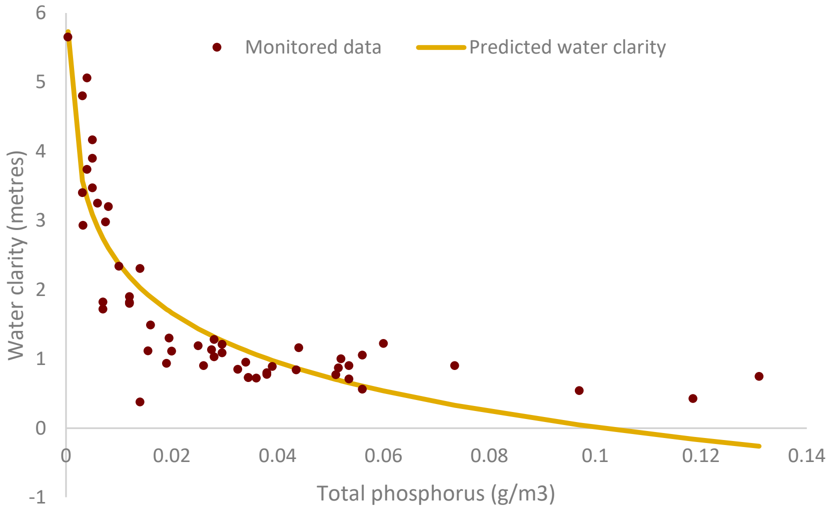
	Model 1	**Model 2**
Predicted variable	Water clarity (metres)	Water clarity (metres)
TP	-11.3175***	
Log TP		-0.896***
Constant	2.619***	-1.259***
N	520	520
R^2	0.09	0.32

*** = significant at the 0.1% level

We analysed the data at the regional level for the three major regions of interest (Canterbury, Southland and Waikato). The data for Canterbury and Waikato were similarly unable to predict much of the variation in water clarity (R^2 = 0.23 and 0.35 respectively) but were for Southland (R^2 = 0.79). The modelled results using a log model are shown in Figure 14.[85] These findings are consistent with those of Ian Jowett who was also able to develop a log model for predicting water clarity in Southland from TP.[86]

[85] Water clarity = -1.02589.$\log_e$(TP) – 2.34931
[86] Jowett in Denne *et al* (2013)

Figure 14 Relationship between total phosphorus concentration and water clarity - Southland



Source: analysis of MfE data – River water quality state 2013-2017.

Although the data for Southland look to provide a useful basis for a predictive model, the national level data, or that for other regions, do not provide an adequate basis for predicting water clarity.