**BEFORE THE PROPOSED NATURAL RESOURCES PLAN HEARINGS PANEL**

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| **IN THE MATTER** | of the Resource Management Act 1991 |
| **AND** | |
| **IN THE MATTER**<br>**AND** | of Water quality |
| **IN THE MATTER** | of the submissions and further submissions set out in the S42a Officer Report |

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**STATEMENT OF PRIMARY EVIDENCE OF RICHARD GOODWIN STOREY ON BEHALF OF WELLINGTON REGIONAL COUNCIL**

**TECHNICAL – WATER QUALITY**

**12 January 2018**

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## 1. SUMMARY

1.1 My name is Richard Goodwin Storey. I am a freshwater ecologist with 13 years' experience at the National Institute of Water and Atmospheric Research (NIWA). I have a Ph.D. in Zoology from University of Toronto and a M.Sc. in Zoology from University of Auckland. I am a member of the Society for Freshwater Science and the New Zealand Freshwater Sciences Society. My area of expertise is in the ecology of aquatic macroinvertebrates, the biological assessment and rehabilitation of streams, and ecological modelling to support freshwater decision-making. In regard to the latter, I have developed a decision-support model for the Ruamahanga catchment in Wellington Region, which involved extensive analysis of ecological and hydrological data from this catchment and consultation with scientists familiar with the catchment. A full copy of my qualifications and experience is available in **Attachment A** of my evidence.

1.2 I have been asked to provide evidence in response to submissions received coded to topic Water Quality for the following specific matters/areas/schedules:

(a) And the relationship between dissolved nutrients and MCI values in Wellington streams and rivers.

(b) And setting region-wide nutrient limits as a means for raising MCI values to meet target values in Wellington streams and rivers.

1.3 The scope of my evidence includes

(a) assessing submissions relating to nutrient management as a means for achieving target MCI values in streams and rivers of the Wellington region, including the technical rigour of the methodologies in these submissions and the appropriateness of setting region-wide nutrient limits for achieving target MCI values.

(b) Summary of alternative methods for deriving a relationship between nutrients and MCI, and for achieving target MCI values.

1.4 The methodology for assessing submissions involved review of published literature and technical reports regarding the relationship between MCI values and

(a) dissolved nutrients

(b) other environmental factors

in streams and rivers in New Zealand and other countries.

1.5 My Evidence addresses matters raised in the submissions of Adam Canning and Russell Death.

1.6 Summary of recommendations

(a) MCI has been shown to be correlated with a decrease in native vegetation cover and an increase in “heavy” pastoral land use in the catchment (Clapcott et al. 2013). A variety of stressors are associated with a change in land use from native vegetation to pastoral agriculture or urban development. Studies have shown that stressors associated with decreased MCI scores following such land use change include elevated water temperature (Quinn et al. 1997a, Collier 1995), fine sediment deposition (Niyogi et al. 2007, Clapcott et al. 2011, Wagenhoff et al. 2011), suspended sediment, excess periphyton growth (Quinn and Hickey 1990, Collier 1995, Matheson et al. 2015), and altered hydrology (Booker et al. 2015; Greenwood et al. 2016).

(b) Expert consensus is that where nutrients are correlated with MCI the causative link is via the effect of nutrients in increasing periphyton biomass, which alters habitat and food quality for stream macroinvertebrates (Miltner 1998, Dodds and Welch 2000, Greenwood et al. 2016, Clapcott et al. 2017). The relationship between nutrients and periphyton biomass may or may not be strong, depending on factors such as light, temperature and frequency of high flows (Snelder et al. 2014).

(c) In my opinion, the approach of achieving target MCI levels in streams by reducing dissolved nutrient concentrations alone (as recommended by Death and Canning) is too simplistic and may be ineffective in many stream reaches.

(d) The reason is that reducing one of the stressors affecting macroinvertebrate communities while not reducing others will not result in significant change to the macroinvertebrate community except where that one stressor is the main cause of degradation in the macroinvertebrate community.

(e) Because of this, effective management to increase MCI levels requires understanding the main stressor(s) that are currently impacting on the macroinvertebrate community in each stream reach. The main stressors are likely to vary depending on catchment land use (e.g. urban catchments place a different suite of stressors on stream macroinvertebrate communities than agricultural catchments, including more severely altered hydrology, more heavy metals and polyaromatic hydrocarbons) and stream type (e.g. low gradient soft-bottomed streams are likely to place different stressors on macroinvertebrate communities than high gradient or gravel-bed streams; Collier et al. 1998). Effective management therefore requires identifying the primary stressors in different catchments and stream types, and targeting management actions to address those stressors.

(f) In many stream reaches the macroinvertebrate community will be affected by more than one stressor (Matthaei et al. 2010, Lange et al. 2014). Therefore, in my opinion, an approach more likely to result in improvement in MCI scores is to take management actions that alleviate a range of stressors associated with catchment land use. One example is riparian planting, which can reduce fine sediment and phosphorus (by preventing stock access to streams, stabilizing stream banks and filtering overland runoff) and water temperature (by shading in small to medium streams). Riparian planting may not reduce nitrate unless groundwater flows through the root zone of riparian plants. However, riparian vegetation can weaken the response of periphyton to high nitrate due to the shading it provides (Matheson et al. 2012). In addition it restores terrestrial organic matter inputs that provide food and habitat for macroinvertebrates.

(g) Policies to increase MCI scores must also consider the scale and location of management actions. Current evidence suggests that recolonization by macroinvertebrates is enhanced where restored sites are located close to sources of recolonists (Parkyn et al. 2003) and where riparian buffer strips (if these are the main management action) are larger than a certain width (e.g. 10-20 m; Parkyn 2004) or represent a greater proportion of stream length in a catchment (Collier et al. 2001). In streams distant from high-quality habitats, reducing stressors may not result in increases in MCI for many years or decades, as macroinvertebrates are unable to recolonize the stream (Parkyn and Smith 2011, Tonkin et al 2014, Leps et al. 2016).

## 2. INTRODUCTION

2.1 My name is Richard Goodwin Storey. I am a freshwater ecologist with 13 years' experience at the National Institute of Water and Atmospheric Research (NIWA). I have a Ph.D. in Zoology from University of Toronto and a M.Sc. in Zoology from University of Auckland. I am a member of the Society for Freshwater Science and the New Zealand Freshwater Sciences Society. My area of expertise is in the ecology of aquatic macroinvertebrates, the biological assessment and rehabilitation of streams, and ecological modelling to support freshwater decision-making. In regard to the latter, I have developed a decision-support model for the Ruamahanga catchment in Wellington Region, which involved extensive analysis of ecological and hydrological data from this catchment and consultation with scientists familiar with the catchment. A full copy of my qualifications and experience is available in **Attachment A** of my evidence.

2.2 I have been engaged by Great Wellington Regional Council to provide evidence relating to the Proposed Natural Resources Plan for Water Quality.

## 3. CODE OF CONDUCT

3.1 I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note and that I agree to comply with the code. My evidence in this statement is within my area of expertise. I have not omitted to consider material facts known to me that might alter to detract from the opinions which I express.

## 4. SCOPE

4.1 I have been asked to provide evidence in response to submissions received coded to topic Water Quality for the following specific matters/areas/schedules:

(a) Assessment of the relationship between dissolved nutrients and MCI values in Wellington streams and rivers.

(b) And setting region-wide nutrient limits as a means for raising MCI values to meet target values in Wellington streams and rivers.

4.2 The scope of my evidence includes

(a) assessing submissions relating to nutrient management as a means for achieving target MCI values in streams and rivers of the Wellington region, including the technical rigour of the methodologies in these submissions and the appropriateness of setting region-wide nutrient limits for achieving target MCI values.

(b) Summary of alternative methods for deriving a relationship between nutrients and MCI, and for achieving target MCI values.

## 5. SUMMARY OF SUBMISSIONS ADDRESSED BY MY EVIDENCE

5.1 Russell Death's report "Ecosystem health and nutrient concentrations for Wellington rivers and streams."

(a) Dr. Death compares predicted MCI (Macroinvertebrate Community Index) scores of REC (River Environment Classification) reaches in the Wellington Region with target values set in the Proposed Natural Resources Plan. He finds that predicted MCI values are below target values for the corresponding stream type in approximately 93% of REC reaches.

(b) He states that critical management parameters to maintain ecosystem health should include nitrate-nitrogen and dissolved reactive phosphorus.

(c) He estimates a simple correlation relationship between MCI and nitrate concentration in each of four datasets. The first of these involves modelled MCI related to modelled nitrate in over 500,000 stream reaches. The second involves measured MCI values related to modelled nitrate concentrations in 962 sites. The third involves an unspecified dataset. The fourth involves measured MCI related to measured nitrate values in 62 sites.

(d) He uses either the first of these correlations, or all four (it is unclear which) to derive a target nitrate and a DRP value that corresponds to the target MCI score in the PNRP.

(e) He compares the current nitrate and DRP values (presumably modelled nitrate and DRP) to target values for each stream type in the Wellington region. Using this method, he finds that 8-98% of river reaches have nitrate concentrations exceeding target levels and 9-35% of river reaches have DRP concentrations exceeding target levels.

## 6. METHODOLOGY

6.1 The methodology for assessing submissions involved review of the models that produced the datasets used by Dr. Death, and review of published literature and technical reports regarding the relationship between macroinvertebrate metrics (particularly MCI values) and

(a) dissolved nutrients

(b) other environmental factors

in streams and rivers in New Zealand and other countries.

6.2 Documents that were referred to in preparing this evidence include the PNRP and the references listed at the end of this evidence.

6.3 Issues raised in submissions include:

(a) Validity of the correlations between MCI and nutrients in datasets containing modelled data only.

(b) The strength of correlations using measured values of MCI and nutrients.

(c) Lack of consideration of other factors likely to influence MCI values in addition to nutrients, particularly in urban catchments.

(d) Lack of consideration of the pathway by which nutrients may affect MCI, and what other factors may influence this pathway.

(e) Appropriateness of nitrate and dissolved reactive phosphorus as the most relevant measures of available nitrogen and phosphorus, respectively

(f) Applying a single relationship between MCI and dissolved nutrients to all stream types in the region.

(g) The implied assumption that MCI will improve when a stressor is reduced.

# 7. RESULTS

## 7.1 Validity of the correlations between modelled MCI and modelled nutrients

(a) Death (2015) derives the correlation between MCI and nutrients (nitrate and DRP) at least partly (possibly entirely) by relating modelled MCI values to modelled nutrient values. The modelled MCI values are taken from Clapcott et al. (2013). In this dataset, MCI values are predicted for each REC (River Environment Classification) reach in New Zealand on the basis of a number of (mostly catchment-level) physicochemical variables in GIS databases that the authors showed to be correlated with MCI at monitoring sites. The two most influential variables “driving” the model (i.e. determining the resultant MCI values) are % indigenous vegetation and % heavy pastoral land use. The modelled nutrient values are taken from Unwin and Larned (2013). In this dataset, nutrient values are predicted for each REC (River Environment Classification) reach in New Zealand on the basis of a number of (mostly catchment-level) physicochemical variables shown to be correlated with the two nutrients at monitoring sites. The two most influential variables “driving” the nitrate model (i.e. determining the resultant nitrate values) are % heavy pastoral land use and % indigenous vegetation, while the two most influential variables “driving” the DRP model (i.e. determining the resultant DRP values) are catchment-averaged sediment particle size and catchment mean slope. Given that the same two physicochemical factors are used to predict both nitrate and MCI, it is not surprising that there is a strong correlation between these two variables in the modelled dataset. This correlation, therefore, reveals nothing except that both are correlated with land use. The correlation between MCI and DRP is more informative, since each is predicted by different factors.

## 7.2 The strength of correlations using measured values of MCI and nutrients

(a) Death (2015) states that the correlation between MCI and nitrate for “real”, i.e. measured, data has an $r^2$ of 0.24 (though it is not clear which dataset he is referring to). This means that nitrate explains 24% of the variance in MCI in this dataset. This is a relatively low proportion, which implies that other factors are important in determining the final MCI value in addition to nitrate. The correlation between MCI and DRP also has an $r^2$ of 0.24.

**7.3 Other factors likely to influence MCI in addition to nitrate**

(a) Death (2015) considers only a bivariate (simple) correlation between MCI and nitrate (first) and DRP (second), without accounting for a number of other factors that are known to influence MCI. This is likely to be the main reason that the correlations from measured datasets had relatively low $r^2$ values. The strong correlations in modelled datasets show that both nitrate and MCI are associated with a decline in catchment indigenous vegetation cover and an increase in catchment “heavy” pastoral cover. These changes in land use are also associated with increased light at the riverbed (which promotes periphyton growth), elevated water temperatures, loss of riparian vegetation as habitat for adult aquatic insects, increased deposited and suspended fine sediment, a shift in food resources from terrestrial organic matter to periphyton, loss of instream habitat complexity and more rapid and extreme changes in flow (Duncan 1995, Quinn 2000). All of these changes are known to affect macroinvertebrates (Collier and Smith 2000, Matthaei et al. 2010, Quinn et al. 1994, Quinn et al. 2000) and many of them are associated with a decline in MCI (Quinn and Hickey 1990, Quinn et al. 1997a, Collier 1995, Stark and Maxted 2007, Niyogi et al. 2007, Clapcott et al. 2011, Wagenhoff et al. 2011, Matheson et al. 2015, Booker et al. 2015). By not accounting for these other important factors, Dr. Death has not made a convincing case that there is a cause-effect relationship between MCI and nutrients. Indeed, from the data provided it could be argued that MCI is responding primarily to changes in one or more of these other factors, and nitrate is simply associated with these changes. This is important in the context of the submissions by Canning and Death because efforts to reduce nutrients may not result in improvements in MCI if they do not include amelioration of other stressors associated with land use change.

**7.4 The pathway by which nutrients may affect MCI**

(a) Death (2015) assumes a causal relationship between nutrients and MCI. A causal relationship is likely to exist, but it is unlikely to be a direct relationship (unless nitrate reaches concentrations toxic to invertebrates). Consensus among an expert panel of New Zealand stream ecologists (Clapcott et al. 2017) is that “the most likely causal pathway from nutrients to macroinvertebrates [is] via periphyton proliferation”. This is also the prevailing view in international literature (e.g. Miltner 1998, Dodds and Welch 2000). The mechanism underlying this pathway is that excessive periphyton growth leads to a change in the physical habitat and the primary food source available to invertebrates, favouring different species than when periphyton growth is low. Periphyton proliferations are generally inhabited by taxa with low MCI scores (Stark and Maxted 2007).

(b) The indirect nature of the MCI-nutrient relationship, which is not made clear in Death (2015), is important because the strength of the relationship between nutrients and MCI depends on factors that influence periphyton growth. These include the frequency of high flow events (especially flows greater than three times the median flow (Biggs 2000; Snelder et al. 2014, Matheson et al. 2015) or flows with enough power to mobilise sand; Hoyle et al. 2017), light at the riverbed, water temperature and riverbed substrate (Quinn et al. 1997b, Matheson et al. 2012, 2015, Snelder et al. 2014). If one of these factors is limiting periphyton growth in a river reach, then reducing nutrients is unlikely to greatly affect MCI. Matheson et al. (2015) conclude that “[because] nutrient availability is one of a number of factors that affect periphyton abundance in rivers, therefore management of periphyton abundance via controls on nutrient concentrations alone is difficult."

**7.5 Appropriate measures of available nitrogen and phosphorus**

(a) Death (2015) uses nitrate as the basis of his correlations and his recommendations for nitrogen management.

(b) This is in contrast with most authors who have examined relationships between nutrients and periphyton or macroinvertebrates. Matheson et al. (2015) focus on dissolved inorganic nitrogen, which includes ammonium and nitrate as well as nitrate. Ammonium is typically in lower concentrations than nitrate, but can occur in significant concentrations in certain situations, e.g. associated with sewage treatment plant discharges. It is ecologically important as it is taken up more readily than nitrate by periphyton. Other authors, e.g. Dodds et al. (2002) focus on total nitrogen, which includes organic forms, as organic nitrogen can be rapidly transformed into bio-available inorganic forms through microbial action.

(c) *Phormidium*, a type of cyanobacteria that commonly forms nuisance periphytic growths in rivers, can take up and mineralize phosphorus from sediment (McAllister et al. 2016). Therefore, particulate phosphorus may be a more useful variable than dissolved reactive phosphorus (the form discussed by Death (2015) for management of periphyton.

(d) Dodds and Welch (2000) warn that "control [of periphyton] based on measured levels of dissolved inorganic N and P may not be effective because these pools are replenished rapidly by remineralization in surface waters", and therefore recommend managing total nitrogen and total phosphorus.

7.6 **Use of a single correlation to prescribe management in all stream types**

(a) The correlation in Death (2015) is derived from data covering a wide range of stream and catchment types. This correlation may accurately describe a cause-effect (albeit indirect) relationship between MCI and either nitrate or DRP in some Wellington streams. However, for the reasons given above, it is unlikely to accurately describe a cause-effect relationship equally well in all stream types. For example, in urban streams macroinvertebrate communities are known to be affected primarily by altered hydrology, in addition to habitat simplification, fine sediment, metals and hydrocarbons, more than by dissolved nutrients (Storey et al. 2013, Harding et al. 2016). In lowland, low gradient, soft-bottomed streams, periphyton may not grow well due to lack of hard substrate, and the relationship between nutrients and macroinvertebrates may be different than the one described by Death (2015) (Collier et al. 1998, Stark and Maxted 2007, Wilcock et al. 2007, Greenwood et al. 2012). Moore (2014) shows that among lowland streams of the Canterbury Plains there is little if any relationship between MCI and nitrate. Indeed, the macroinvertebrate community itself is very different in soft-bottomed to hard-bottomed streams, requiring a different (soft-bottom) MCI (Stark and Maxted 2007). The approach taken by Death (2015) and Canning does not take account of the different relationship between MCI and nutrients in different stream types. This creates a risk that nutrient management in certain stream types may be ineffective in improving MCI scores.

### 7.7 The assumption that MCI will improve when a stressor is reduced or removed

(a) Death (2015) and Canning (2017) do not state explicitly the assumption that MCI will improve when a key stressor is alleviated. However, it is implied by their recommendation to reduce dissolved nutrients in order to meet target MCI values. Only limited data are available to address this assumption, and results have been variable. In some cases the macroinvertebrate community has recovered in association with alleviation of a stressor (e.g. Quinn et al. 2009) whereas in others it has shown minimal change (e.g. Parkyn et al. 2003, Leps et al. 2016). The reasons for this variability are not well established, but possible reasons are the inability of invertebrates to recolonise from source habitats (Parkyn and Smith 2011), resistance to new arrivals by the “degraded” macroinvertebrate community, and lack of habitat for all life stages of invertebrates. This means that if stream water or habitat quality are improved in a stream distant from healthy (diverse) habitats, changes in MCI are unlikely to occur within the space of a few years (Parkyn et al. 2003, Parkyn and Smith 2011, Tonkin et al. 2014). Recolonisation may occur eventually (over longer time periods than have been monitored thus far), but may require decades (Leps et al. 2016).

### 7.8 Alternative methods of deriving a relationship between dissolved nutrients and macroinvertebrates

(a) Wagenhoff et al. (2017) provide stronger evidence than Death (2015) that a cause-effect relationship exists between nutrients and macroinvertebrates, because they

- Use measured rather than modelled data
- Account for the effects of collinear (correlated) variables on macroinvertebrates

(b) Note that their analysis is based on macroinvertebrate “species turnover” rather than change in MCI. However, species turnover is likely to be related to change in MCI, since the species that decline with increased nutrients are pollution-sensitive with high MCI tolerance scores. In terms of nutrients, they use total nitrogen rather than nitrate. The majority of total nitrogen may be nitrate, but it also includes other dissolved species such as ammonium and also organic forms (dissolved and particulate).

(c) Wagenhoff et al. (2017) find maximum species turnover (mainly due to decreases in sensitive species) occurs at total nitrogen concentrations <0.5 mg/L. Given that total nitrogen includes nitrogen species other than nitrate, this is in the same range to the concentrations recommended by Death (2015) as limits for nitrate (0.18-0.27 mg/L for mid-gradient hard and soft sedimentary streams, 0.25-0.61 mg/L for most lowland streams and rivers).

(d) As other authors do, Wagenhoff et al. (2017) acknowledge that the relationship between nutrients and macroinvertebrates is largely via effects on periphyton biomass.

(e) Despite Wagenhoff et al.'s sophisticated statistical analysis, it remains clear that in some environments there is no clear relationship between nitrate and MCI (Moore 2014).

### 7.9 Alternative methods to achieve MCI target values in Wellington streams

(a) Effective management to increase MCI levels requires understanding the main stressor(s) that are currently impoverishing the macroinvertebrate community in each stream reach. The main stressors are likely to vary depending on catchment land use (e.g. urban catchments place different stressors on stream macroinvertebrate communities than agricultural catchments; Storey et al. 2013, Harding et al. 2016) and stream type (e.g. low gradient soft-bottomed streams are likely to place different stressors on macroinvertebrate communities than high gradient or gravel-bed streams; Collier et al. 1998). Therefore, reducing nutrients may not be the most effective way to achieve an increase in MCI in all streams. For example, Parkyn et al. (2003) found that among nine Waikato streams with replanted riparian zones, increases in QMCI over time were most strongly related to reductions in water temperature. Wilcock et al. (2007) suggest that streams with soft substrate, not discharging to lentic systems and with low macrophyte cover are largely exempt from nutrient management. Effective management therefore requires identifying the primary stressors in different catchments and stream types, and targeting management actions (or setting limits) that address those stressors.

(b) In most Wellington streams with reduced MCI scores, multiple stressors are likely to be affecting the macroinvertebrate community. Therefore, in my opinion, the most effective management actions to increase MCI scores will be those that reduce a range of stressors. In agricultural catchments one management action that typically reduces a range of stressors is replanting of riparian areas with trees and other tall vegetation. Riparian “buffer” strips of this type typically reduce fine sediment and phosphorus (by preventing stock access to streams, stabilizing stream banks and filtering overland runoff) and water temperature (by shading in small to medium streams). In addition riparian vegetation restores terrestrial organic matter inputs that provide food and habitat for macroinvertebrates.

(c) Management to increase MCI could also include measures that decouple dissolved nutrient concentration from MCI. For example, although riparian planting may not reduce nitrate significantly if buffers are narrow and/or groundwater flows bypass the root zone of riparian plants, it can reduce periphyton growth even in the presence of high nitrate due to the shading it provides. Note, however, that this approach may not reduce nitrate export to downstream receiving waters.

## 8. CONCLUSIONS – addressing submissions

8.1 Death (2015) shows a correlation between MCI and each of nitrate and phosphate for a) modelled data from over 500,000 reaches throughout New Zealand, and b) measured data from several hundred sites in the lower North Island. On the basis of these correlations, Death (2015) and Canning (2017) recommend reducing nitrate and phosphate as the primary means to raise MCI levels in Wellington streams.

8.2 In my opinion, this logic is flawed because

(a) The correlation between modelled MCI and modelled nitrate is probably inflated due to an artefact of the modelling process.

(b) The correlation does not demonstrate that nutrients are the only or even the primary stressor depressing MCI scores in the sites represented by Death's (2015) data. Both nutrients and MCI are likely to be correlated with a suite of stressors associated with a change in land use from native vegetation to pastoral agriculture or urban development.

(c) A causal link between nutrient concentrations and MCI is probably via periphyton growth. In any stream reach, the relationship of nutrients with periphyton (and therefore with MCI) may be strong or weak depending on various other environmental factors that affect periphyton growth.

8.3 Because of these issues, reducing nitrate and dissolved reactive phosphate concentrations to raise MCI scores is unlikely to be effective in every stream reach in the Wellington region.

8.4 In my opinion, a more effective strategy to raise MCI scores would involve

(a) Actions that reduce a wider range of stressors and restore a variety of ecological processes

(b) Identifying the different stressors impacting different stream types, and streams with different catchment land use, and focusing management actions on alleviating the primary stressors in each situation.

8.5 An important consideration not mentioned by Death (2015) is that attempting to restore stream macroinvertebrate communities by removing environmental stressors inevitably involves high uncertainty, particularly where a stream is far from sources of potential recolonist invertebrates.

## 9. CONCLUSION

9.1 My evidence provides recommendations regarding submissions made on the setting of nutrient limits to achieve target MCI levels under Proposed Natural Resources Plan topic Water Quality.

## 10. REFERENCES


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# Attachment A
# Qualifications and experience

## Curriculum Vitae
## PART 1

| 1a. Personal details | | | | | |
|---|---|---|---|---|---|
| **Full name** | *Title* Dr. | *First name* Richard | *Second name(s)* Goodwin | *Family name* Storey | |
| **Present position** | Freshwater Ecologist | | | | |
| **Organisation/Employer** | National Institute of Water and Atmospheric Research, Ltd. | | | | |
| **Contact Address** | Gate 10, Silverdale Road | | | | |
| | Hillcrest | | | | |
| | Hamilton | | **Post code** | 3216 | |
| **Work telephone** | 07 859 1880 | **Mobile** | 027 366 0481 | | |
| **Email** | Richard.storey@niwa.co.nz | | | | |

### 1b. Academic qualifications

- 2001 Ph.D. in Zoology, University of Toronto
- 1995 M.Sc. with First Class Honours in Zoology, University of Auckland
- 1992 B.Sc. in Zoology and Botany, University of Auckland

### 1c. Professional positions held

| | |
|---|---|
| 2007-present | Freshwater Ecologist, NIWA |
| 2004-2007 | Postdoctoral Fellow, NIWA |
| 2002-2004 | Scientific Officer, A Rocha Lebanon |

### 1d. Present research/professional speciality

Restoration ecology of streams and rivers; citizen science; biological monitoring of rivers; ecology and hydrology of intermittent and headwater streams; ecology of urban streams; Bayesian Belief Networks for freshwater decision-making; nitrogen cycling and emissions in streams and wetlands.

| 1e. Total years research experience | 22 years |
|---|---|

### 1f. Professional distinctions and memberships (including honours, prizes, scholarships, boards or governance roles, etc)

- *2017-present Coordinator, National Advisory Group on Volunteer Freshwater Monitoring*
- *2017-present Society for Freshwater Science member*
- *2015-present Steering Committee, NZ Landcare Trust Citizen Science Initiative*
- *2004-07 FRST NZ Science and Technology Postdoctoral Fellowship*
- *2000 University of Toronto Fellowship*
- *1995-98 University of Toronto Connaught Scholarship*
- *1991 Senior Scholarship in Zoology*
- *1994-present New Zealand Freshwater Sciences Society member*

| 1g. Total number of *peer reviewed* publications and patents | Journal articles | Books, book chapters, books edited | Conference proceedings | Patents |
|---|---|---|---|---|
| | 17 | 2 | 0 | 0 |

**PART 2**

| 2a. Research publications and dissemination |
|---|



| Peer-reviewed journal articles |
|---|
| Neale, M. W., **Storey, R. G.**, & Rowe, D.K. (2017) Stream Ecological Valuation (SEV): revisions to the method for assessing the ecological functions of New Zealand streams. Australasian Journal of Environmental Management. In press.<br>**Storey, R. G.,** & Wright-Stow, A. (2017). Community-based monitoring of New Zealand stream macroinvertebrates: agreement between volunteer and professional assessments and performance of volunteer indices. New Zealand Journal of Marine and Freshwater Research, 1-18. doi: 10.1080/00288330.2016.1266674<br>**Storey, R. G.,** Reid, D. R., & Smith, B. J. (2017). Oviposition site selectivity of some New Zealand aquatic macroinvertebrate taxa and implications for stream restoration. New Zealand Journal of Marine and Freshwater Research, 1-17. doi: 10.1080/00288330.2016.1269351<br>Graham, S. E., **Storey, R.,** & Smith, B. (2017). Dispersal distances of aquatic insects: upstream crawling by benthic EPT larvae and flight of adult Trichoptera along valley floors. New Zealand Journal of Marine and Freshwater Research, 1-19. doi: 10.1080/00288330.2016.1268175<br>**Storey, R.,** Wright-Stow, A., Kin, E., Davies-Colley, R., Stott, R. (2016). Reliability of community-based monitoring data: a basis for increased community involvement in freshwater decision-making. Ecology and Society 21:32 https://doi.org/10.5751/ES-08934-210432<br>**Storey, R.** (2015) Macroinvertebrate community responses to duration, intensity and timing of annual dry events in intermittent forested and pasture streams. Aquatic Sciences: 1-20. 10.1007/s00027-015-0443-2<br>**Storey, R.G.,** Quinn, J.M. (2013) Survival of aquatic invertebrates in dry bed-sediments of intermittent streams: temperature tolerances and implications for riparian management. Freshwater Science, 32(1).<br>**Storey, R.G.,** Quinn, J.M. (2011) Life histories and life history strategies of invertebrates inhabiting intermittent streams in Hawke's Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research, 45(2): 213-230. 10.1080/00288330.2011.554988<br>**Storey, R.G.,** Parkyn, S., Neale, M.W., Wilding, T., Croker, G. (2011) Biodiversity values of small headwater streams in contrasting land uses in the Auckland region. New Zealand Journal of Marine and Freshwater Research, 45(2): 231-248. 10.1080/00288330.2011.555410<br>**Storey, R.G.,** Quinn, J.M. (2008) Composition and temporal changes in macroinvertebrate communities of intermittent streams in Hawke's Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research, 42(1): 109-125. 10.1080/00288330809509941<br>**Storey, R.G.,** Dudley Williams, D. (2004) Spatial responses of hyporheic invertebrates to seasonal changes in environmental parameters. Freshwater Biology, 49(11): 1468-1486.<br>**Storey, R.G.,** Cowley, D.R. (1997) Recovery of three New Zealand rural streams as they pass through native forest remnants. Hydrobiologia, 353(1): 63-76. |
| Peer reviewed books, book chapters, books edited |
| Parkyn, S., Collier, K., Clapcott, J., David, B., Davies-Colley, R., Matheson, F., Quinn, J., Shaw, W., **Storey, R.** (2010) The Restoration Indicator Toolkit: Indicators for Monitoring the Success of Stream Restoration. National Institute of Water and Atmospheric Research, Hamilton, New Zealand: 134.<br>Harding, J., Clapcott, J., Quinn, J., Hayes, J., Joy, M., **Storey, R.,** Grieg, H., Hay, J., James, T., Beech, M., Ozane, R., Meredith, A., Boothroyd, I. (2009) Stream Habitat Assessment Protocols for wadeable rivers and streams in New Zealand. University of Canterbury, Christchurch: 133. |
| Other forms of dissemination (reports for clients, technical reports, popular press, etc) |
| **Storey, R.,** Perrie, A., Wood, S., Hicks, M. (2017) Effects of land and water management on ecological aspects of major rivers in the greater Heretaunga and Ahuriri area. Prepared for Hawke's Bay Regional Council, 2017235HN: 114 p.<br>**Storey, R.,** & Graham, S. E. (2016). What determines recovery rates of invertebrate communities in rehabilitated Taranaki streams? Paper presented at the Freshwater on the edge. Annual meeting of the NZ Freshwater Sciences Society, Invercargill. 5-8 Dec 2016. |

**Storey, R.,** Wright-Stow, A., Kin, E., Davies-Colley, R., & Stott, R. (2016). Can community-based monitoring data be used to improve stream restoration science? Paper presented at ERA2016: restoring resilience across all environments. Joint conference of the Society for Ecological Restoration Australasia and the NZ Ecological Society, Hamilton. 19-23 Nov 2016.

**Storey, R.,** Wright-Stow, A., Davies-Colley, R., Kin, E., van Hunen, S., & Stott, R. (2016). Improving monitoring capacity and community engagement. Paper presented at the Values, Monitoring and Outcomes Regional Council Forum, Wellington. 5 September 2016.

Kin, E., **Storey, R.,** Wright-Stow, A., & Davies-Colley, R. (2016). Engaging communities in freshwater monitoring: benefits and challenges. NIWA client report HAM2016-046 prepared for Landcare Research. 41 pp.

**Storey, R.,** Jobert, S., Quinn, J., Fowles, C. (2014) Connectivity and macro-invertebrate drift influence stream restoration outcomes. New Zealand Freshwater Science Society Annual Meeting. Blenheim, 24-27 Nov 2014.

**Storey, R.** (2014) A long-term monitoring programme to assess the effectiveness of two stream restoration projects in the Manawatu Region. NIWA Client Report HAM2014-020 prepared for Horizons Regional Council: 24p.

**Storey, R.** (2013) Biological monitoring of rivers in Gisborne District: Benefits, costs and recommendations. NIWA Client Report HAM2013-007 prepared for Gisborne District Council: 23p.

Davies-Colley, R., Verburg, P., Hughes, A., **Storey, R.** (2012) Variables for regional water monitoring underpinning national reporting: variables for national freshwater monitoring, NIWA Client report HAM2012-006 prepared for Ministry for the Environment. 65p.

Davies-Colley, R.J., Hughes, A.O., Verburg, P., **Storey, R**. (2012) Freshwater Monitoring Protocols and Quality Assurance (QA) National Environmental Monitoring and Reporting (NEMaR) Variables Step 2, NIWA Client Report HAM2012-092 prepared for Ministry for the Environment. 104p.

**Storey, R.G.** (2012) Freshwater Environments of New Zealand: Physical and biological characteristics of the major classes, NIWA Client report HAM2012-159 prepared for Department of Conservation: 60p.

**Storey, R.,** Quinn, J., Wadhwa, S., Fowles, C. (2011) Invertebrate recovery in restored streams: effects of connectivity to source populations. Annual meeting of the New Zealand Freshwater Sciences Society and the Australian Limnological Society, Brisbane, 26-30 September 2011.

**Storey, R.G.**, Neale, M.W., Rowe, D.K., Collier, K.J., Hatton, C., Joy, M., Maxted, J., Moore, S., Parkyn, S., Phillips, N., Quinn, J. (2011) Stream Ecological Valuation (SEV): a method for assessing the ecological functions of Auckland streams. Auckland Council Technical Report 2011/009: 66p.

**Storey, R.** (2010) Aquatic biodiversity values of headwater streams in the Wellington region, NIWA Client Report HAM2010-095 prepared for Greater Wellington Regional Council. 47p.

**Storey, R.** (2010) Riparian characteristics of pastoral streams in the Waikato region, 2002 and 2007. NIWA Client Report HAM2010-022 prepared for Waikato Regional Council. 57p.

**Storey, R.,** Croker, G. (2010) Ecological evaluation and recommendations for restoration of urban streams in Waitakere City. NIWA Client Report HAM2010-125 prepared for Waitakere City Council: 84p.

**Storey, R**., Gadd, J. (2010) Project Twin Streams: Stage 3 ecosytem health monitoring action Plan. NIWA Client Report HAM2010-126 prepared for Waitakere City Council: 40p.

**Storey, R.** (2007) Aquatic invertebrate diversity and distribution at Aammiq Marsh, Lebanon. Report for A Rocha Lebanon.

## 2b. Previous research work

**Research title:** Bayesian Networks to support freshwater decision-making in the Ruamahanga catchment

**Principal outcome:** Predict the outcomes for selected ecological, recreational and aesthetic attributes in the Ruamahanga River and its major tributaries under possible future scenarios.

**Principal end-user and contact:** Greater Wellington Regional Council, Natasha Tomic.

**Research title:** Habitat constraints for aquatic rehabilitation
**Principal outcome:** Determine dispersal abilities and egg-laying habitat requirements of aquatic insects; determine landscape-scale factors driving variable responses to stream rehabilitation efforts.
**Principal end-user and contact:** Taranaki Regional Council, Chris Fowles

**Research title:** Monitoring recovery in Waikato Clean Streams
**Principal outcome:** Determine recovery trajectories for a suite of water quality, habitat and biological variables across seven streams restoring riparian vegetation under Waikato Regional Council's Clean Streams programme
**Principal end-user and contact:** Waikato Regional Council, Michael Pingram

**Research title:** Revision of the Stream Ecological Valuation (SEV)
**Principal outcome:** Lead revisions of the SEV, the main tool used in Auckland and Wellington regions for determining the ecological values of streams and calculating offset mitigation required when urban developments impact on streams
**Principal end-user and contact:** Auckland Council, Martin Neale (now at Martin Jenkins)