BEFORE THE ENVIRONMENT COURT

In the matter of	appeals under clause 14 of the First Schedule to the Resource Management Act 1991 concerning proposed One Plan for the Manawatu-Wanganui region.
between	**FEDERATED FARMERS OF NEW ZEALAND ENV-2010-WLG-000148**
and	**MINISTER OF CONSERVATION ENV-2010-WLG-000150**
and	**HORTICULTURE NEW ZEALAND ENV-2010-WLG-000155**
and	**WELLINGTON FISH & GAME COUNCIL ENV-2010-WLG-000157**
	Appellants
and	**MANAWATU WANGANUI REGIONAL COUNCIL** *Respondent*

STATEMENT OF TECHNICAL EVIDENCE BY Ms CORINA JODI JORDAN ON THE TOPIC OF WATER QUALITY AND NUTRIENT MANAGEMENT

ON BEHALF OF WELLINGTON FISH & GAME COUNCIL

Dated: 14 March 2012

1. INTRODUCTION

Qualifications and experience

1.1 My full name is Corina Jodi Jordan

1.2 I am an Environmental Officer with Wellington Regional Fish and Game Council (WFGC), and I have the following qualifications:

- Batchelor of Science Undergraduate degree majoring in Genetics and Zoology from Massey University (2007)
- 1st Class Honours in Natural Resource Management at Massey University (2008)

1.3 I am currently completing a doctorate in Aquatic ecology with the Institute of Natural resources at Massey University, on Integrated Catchment Management to maintain New Zealand's freshwater fish.

1.4 Prior to my employment with Wellington Fish and Game I was employed for 3 years by the Allan Wilson Center (Massey University) as a Molecular Ecologist specialising in ecology, species diversity and habitat requirements, genetics, and evolution. I have three published papers from this research.

1.5 I have been employed by the Wellington Fish and Game Council since 2008. The Wellington Fish and Game region encompasses the lower North Island, extending from north of Waiouru across to Norsewood and south to Cook Straight. This largely overlaps with the Wanganui Manawatu Regional Council (Horizons) and Greater Wellington Regional Council areas. My professional responsibilities include the development, management, and implementation of the Councils habitat quality and population monitoring programmes as required under the Conservation and Wildlife Acts. As part of this requirement I have reviewed and updated our population monitoring programmes, and habitat monitoring programmes, in order to assess the state and trends of the regions trout fisheries, and state and trends of water quality and aquatic habitat condition in the region. I undertake annual population assessments which include drift dive assessments of the adult trout fishery, electric fishing and spotlighting assessments of our adult and juvenile trout fisheries; and spawning surveys as part of recruitment assessments. Habitat assessment monitoring includes assessing state and trends in water quality, macroinvertebrate community health, periphyton, deposited sediment, and physical habitat condition. Physical habitat monitoring includes assessments of pools, runs, riffles, and the health of riparian habitats.

1.6 Over the last four years I have become familiar with a wide range of environmental issues pertaining to the Horizons' region including: the impacts of point and non point source pollution; increasing abstraction pressures, and rural and urban water supplies; breaches in resource consents conditions; and the health of the regions wetlands, gamebird, surface water, and trout populations.

1.7 As part of my job with WFGC I also provide technical advice on consent applications, Regional Policy Statements, and Regional Plans. This involves assessing notified resource consent applications, regional policy statements and regional and district plans, for their effect on the regions game bird, trout fishery, and recreational hunting and angling values. Since 2007, I have been involved in the technical and planning assessment of over 132 resource consent applications, which included 14 consent applications for discharges of treated domestic wastewater to various waterbodies. I have also provided statements of evidence in 32 local hearings, included Horizons Proposed One Plan and Greater Wellingtons Proposed Regional Policy Statement. I have participated in 29 Formal Environment Court mediations, including Horizons Proposed One Plan, Greater Wellingtons proposed Regional Policy Statement, and Masterton Wastewater.

1.8 My job also entails: liaison with public interest groups, recreational hunters and anglers. As part of my role, I have talked at local and international conferences.

1.9 I have three years research experience specialising in Molecular Ecology at the Allan Wilson Center (Massey University), with three published papers.

1.10 For the last three years I have been responsible for co-ordinating the Wellington Fish and Game Councils involvement in the Proposed One Plan. In this capacity I have attended numerous meetings and workshops with Horizons staff and other submitters, along with court assisted mediation.

1.11 I am familiar with the trout water quality, and habitat requirements to which these hearings relate. I am familiar with information contained in the technical evidence bundle pertaining to the issue of water quality and non-point source discharges and with the joint technical expert statement, and supplementary statement, of Dr Roygard, Ms McArthur and Ms Clark (hereafter referred to as Roygard *et al*, 2012a and Roygard *et al*, 2012b). This evidence draws on my knowledge, various published scientific papers and reports, and expert technical evidence presented at the council level hearing as well as further technical evidence presented to the court from Horizons officers, and from the expert witnesses of WFGC and Minister of Conservation.

Evidence presented at the Council hearing

1.12 This evidence replaces the evidence I gave at the Council hearing with is contained in the technical Evidence Bundle that Horizons has filed with the court.

Expert conferencing

1.13 At the date of writing my evidence expert technical conferencing had not been undertaken.

Expert witnesses Code of Practice

1.14 I have read the Environment Court's Code of Conduct for Expert Witnesses as set out in the Court's 2011 Practice Note, and I agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues addressed in this brief of evidence are within my area of expertise.

1.15 I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

2. SCOPE OF EVIDENCE

2.1 I have been asked by the Wellington Fish and Game Council to provide evidence on the state of the regional trout fishery, and discuss the impacts on the fishery of poor water quality and degraded freshwater ecosystem health. My evidence will cover the following matters:

- Provide an introduction to New Zealand Fish and Game, and the national importance of salmonids
- Review the state of the regions recreational trout fishery
- Briefly review the framework of the One Plan and identification of values

- Discuss the regionally significant issue of water quality and aquatic ecosystem health. In this section I will provide examples from three of the regions main trout fishery rivers, the Manawatu River, Mangatainoka River, and the Rangitikei River
- Discuss water quality requirements of trout
- Discuss trout spawning requirements and provide information on the degradation of trout spawning habitat in the region
- Discuss trout habitat requirements and importance of maintaining healthy riparian margins
- Briefly discuss Schedule D – support for the Schedule D standards, and inclusion of deposited sediment standard
- Discuss the impacts of agricultural land use on aquatic ecosystems and recreational trout fisheries

3. INTRODUCTION

New Zealand Fish and Game, Statutory Considerations, & the National Importance of Salmonids

3.1 Although salmonids are an introduced fish, their valued fisheries status is recognised by statute in section 26b of the conservation Act 1987 and the RMA (1991) section 7c (the maintenance and enhancement of amenity values) and 7h (protection of the habitat of trout and salmon).The inclusion of the protection of the habitat of trout and salmon (s7h) in the RMA (1991) is in recognition of the National importance of these species. Freshwater sports fisheries are of high socio economic and socio cultural importance both domestically and internationally, providing a myriad of benefits to society (Weithman, 1999; Welcomme and Naeve 2001; Arlinghaus, Mehner & Cowx 2002).

3.2 In New Zealand the introduction of brown trout (*Salmo Trutta*) was first provided by legislation in 1867, with brown trout being introduced from 1867 – 68, rainbow trout (*Oncorhynchus mykiss*) were introduced from 1878 -1883, and salmon through the early 1900s (Viner, 1987). Trout were immediately successful, forming largely self sustaining populations, widely distributed throughout New Zealand. Owing largely to the availability of free stone gravel bottomed rivers, and cool clean waters, which provided adequate tributary or mainstem spawning for almost all river systems. Our trout fisheries are now among the most internationally recognized trout fisheries in the world, due to the relatively widespread distribution of our salmonid populations and their large size. Anglers generally consider trout greater than 2.7 kg (6 lb), which can be a well conditioned 600mm fish, to be large, while trout in excess of 4.5 kg (10 lb) are considered to be trophy fish. The large size of our fish, as well as the scenic beauty of our country remains part of the reason why New Zealand has been regarded so highly as an anglers mecca.

3.3 The standard picture of New Zealand trout fishing promoted overseas is of an angler fishing some pristine back country or headwater river, usually surrounded by native forest or tussock grassland, in hilly or mountainous country (Figure 1). We are lucky enough to have two such rivers in the Manawatu Whanganui Region. The Manganui o te ao River was granted protection in 1989 under a National Water Conservation Notice in recognition of its: outstanding wild and scenic characteristics, outstanding habitat for Blue Duck or Whio (*Hymenolainmus malacorhynchos*), and its outstanding recreational fishery. The upper and middle Rangitikei River, was granted protection in 1993 under a national water conservation order, in recognition of its: nationally significant trout fishery status, outstanding wild and scenic characteristics, and outstanding wildlife features.

3.4 Trout fishing in rivers is arguably the icon of sports fishing in New Zealand, and trout fishing is undertaken throughout almost all of New Zealand from our: backcountry fisheries, which accounted for 107,800 angler days or 8.4% of total angler days for the 2007/08 season; and headwater fisheries, which accounted for 33,400 angler days or 2.6% of total angler days for the 2007/08 season; to the larger main stem rivers, which accounted for 450,300 angler days or 35% of total angler days for the 2007/08 season; down to our smaller lowland rivers which support a significant amount of fishing in total, contributing 135,800 angler days or 10.6% of total angler days for the 2007/08 season (Unwin, 2009). Lake fisheries, including Lake Rotoiti, Okataina, Tarawere, and the Rotorua Lakes fisheries, also provide nationally and internationally important angling opportunity, and accounted for over 544,000 angler days over the 2007/08 season, which is 42.8% of total angler days (Unwin, 2009).

3.5 The Wellington Fish and Game region which covers the southern districts of the Horizons region, is dominated by river fisheries, with four major catchments (Ruamahanga, Hutt, Manawatu, and Rangitikei) and fifty recognized tributaries or minor catchments. As already discussed the Upper Rangitikei River is our major scenic headwater fishery, as the Manganui o te ao River falls within the Taranaki Fish and Game Region. The Rangitikei, and the Manawatu rivers comprise our larger mainstem rivers, and our smaller lowland rivers include, rivers such as the Pohangina, Mangatainoka, Makuri, Hautapu, and Mangahao rivers. The Mangatainoka, Makuri and Hautapu rivers were granted local water conservation notices in 1991, 1990, and 1989, respectively, under the Soil and

Water Conservation Act 1967 in recognition of their regionally significant trout fishery values.

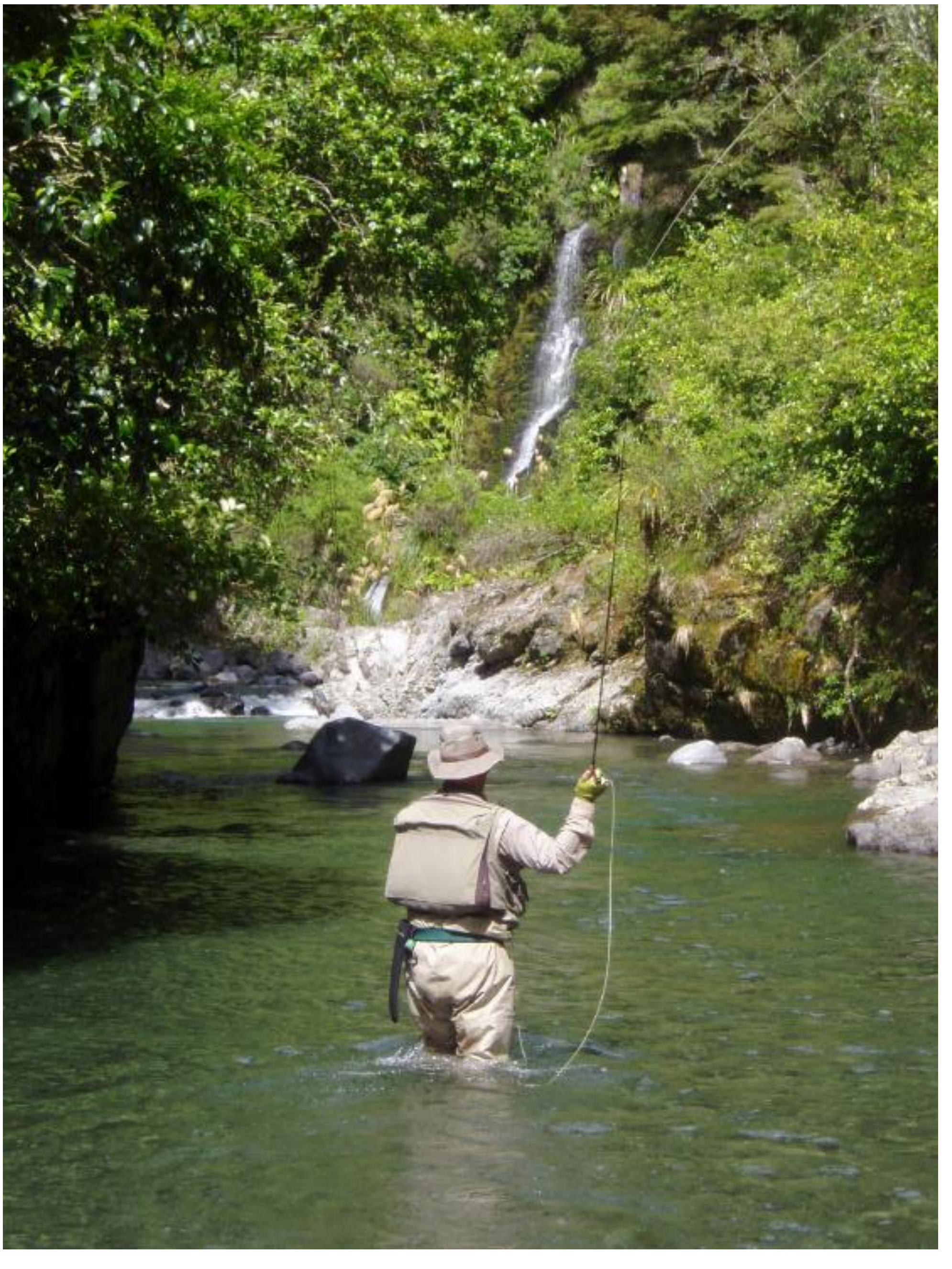

Figure 2. Angler fly fishing in the Upper Rangitikei River

3.6 New Zealands trout fisherys are recognized both internationally and domestically, attracting both local and foreign tourism. At the New Zealand Eco Tourism Conference held in Nelson (2009) the Associate Minister of Tourism, Dr Colman, opened the conference stating that "*tourism generates 20 billion dollars for our economy, 18% of our export earnings*". "*It equates to 9.2% of our GDP and accounts for 1 in 10 jobs*"(Dr Coleman, 2009). He stated that tourism driven by both international visitors and domestic travel "*is big business and a serious industry in NZ*", "*it stimulates regional growth, supports our international connectedness and influences our international reputation*". Domestic tourism has increased by"*6.2% to 8.1 billion dollars in the year to December 2008*", and that "*nature based visitors spent $5 billion on their New Zealand trip – that is 61% of our international visitor expenditure*". He stated that NZ is an "*aspirational destination and visitors wanted to immerse themselves in New Zealand's landscapes, culture and experiences*" (Dr Colman, 2009).

3.7 Trout fishing based tourism is a significant component of these figures, providing the highest rate of income per capita, with the recreational tourist angler spending more on their fishing holiday than any other tourist venture (Tourism New Zealand *pers comm.,* 2009). Figures taken from the National Angling survey undertaken by Martin Unwin of NIWA, show total fishing license sales of 98, 620 for the 2007/08 season, of which overseas anglers accounted for 12.7% (excluding the Lake Taupo fishery). Per capita license sales appear to have increased slightly since the 2001/02 survey. Total angler effort for the 2007/08 season was estimated to be over 1, 271, 300 angler days, of which 68,900 angler days (5.4%) was expended by overseas visitors. Total effort by New Zealand residents differed little from the corresponding figure for the previous two surveys. In acknowledgment of the importance of New Zealand's rivers and their recreational value the associate minister for tourism stated that " *New Zealand's rivers are assets that support tourism and recreational opportunities"*, and that "*promoting and protecting our natural environment makes dollars and sense*" (Dr Colman ,2009).

3.8 Unfortunately, New Zealand's larger rivers, including our iconic headwater fisheries, are coming under increasing pressure from developers including hydroelectricity companies. Our main stem rivers and smaller lowland rivers, which are often the ordinary "*close to home*" fishing sites for many anglers, are coming under increasing pressure from agriculture and horticultural activities, flood protection activities causing ongoing disturbance and channelisation, deforestation, water abstraction, and waste disposal. These impacts have altered our freshwater ecosystems profoundly, probably more than terrestrial ecosystems (Cowx, 2002). As a result the majority of freshwater ecosystems are impacted and the fisheries heavily modified or degraded (Cowx & Gerdeaux, 2004). These impacts have affected trout fisheries disproportionately, due to the relatively high water quality and quantity requirements of salmonids. As a consequence the sustainability of our lowland fisheries is becoming increasingly challenged. The Horizons region is no exception.

4. STATE OF THE RESOURCE - WELLINGTON FISH AND GAMES TROUT FISHERIES

Population Assessments – Drift Diving

4.1 In fulfilment of Fish and Game's statutory requirements, in relation to sports fish, under s26c of the Conservation Act (1987), Wellington Fish and Game sets out in our Annual Operational Plan a programme for monitoring and assessing our regions trout fishery populations. Project 1111 "*Sports Fish Monitoring*" requires Wellington Fish and Game undertake annual drift dive and spawning surveys of our regions main trout fishery rivers, which provides information on population change and recruitment. This information is used to inform regulation setting and resource management purposes, to ensure that the regions trout fisheries are sustainably managed and maintained.

4.2 Drift dive information dates back to 1979, in this region, with regular assessment of the Upper Rangitikei, Hutt, and Waikanae, Rivers. The Makuri, middle and lower Rangitikei, Mangatainoka, Hautapu, Oroua, and Ohau rivers, in the Horizons region, have historically only been dived periodically. In 2004 our sports fish monitoring program was revised, so that 13 rivers, and 43 sites were included in our annual drift dive assessment plan. The Hutt, Upper Rangitikei and Waikane Rivers were still assessed independently, but information from the other rivers was collated to provide a cumulative assessment on the sustainability of the regions trout fisheries. With the complete change in Wellington Fish and Game staff in 2008, our Sportsfish monitoring program was again revised, to include more rivers and a greater number of sites, complemented by habitat mapping.

4.3 Overall, 21 rivers, and 55 sites, are assessed annually via drift diving. These new rivers and drift dive sites have been included as the freshwater resources are coming under increasing pressure from development, intensification of agriculture and horticulture, abstraction, and point source pollution.

Methods

4.4 Drift diving is the most common technique for assessing the abundance of trout in New Zealand rivers and is described in Teirney and Jowett (1990). Sites are chosen which represent the geological diversity of the river, generally upland, middle, and lowland representative reaches are included. The length of each reach is determined by the number of pool/riffle and runs present, and is generally a function of the width of the active channel. Sites generally include 3 character replicates. Divers, properly equipped, form a straight line, spaced evenly across the river at right angles to the river's banks and float with the current looking for trout as they go. Diving generally starts at the beginning of a pool and ends at the beginning of a riffle. The number of small (10 - 20cm), median (20 – 40cm) and large (>40cm) rainbow and brown trout are recorded, and expressed as number of trout, in each category, per kilometre.

4.5 Drift dive counts are considered to generally be underestimates of the total trout population (Teirney & Jowett 1990; Young & Hayes 2001). The degree of underestimation varies from river to river and is probably dependent on the amount of physical cover that is available. However, the proportion of trout that are detected by divers appears to remain relatively constant over time within river reaches (Young & Hayes 2001).

Results

4.6 Drift Dive results over the last 6 years show a significant decline in the Wellington Fish and Game regions trout fisheries ($F = 7.42$, df = 1,3, $P = 0.07$) (Fig. 2). With rivers, such as the Mangatainoka and Makakahi, driving this downward trend, both of which were granted Local Water Conservation Notices due to their Regionally Significant trout fishery value. The Mangatainoka River (Fig. 3), has dropped from ~ 31 trout per km in 1981, and ~ 96 trout per km in 1987 to current levels of 7 trout per km ($F = 7.52$, df = 1,9, $P = 0.02$), while the Makakahi has dropped from 10 trout /km in 2006 to current levels of 2 trout/km ($R^2 = 0.99$, $F = 243$, df = 1,2, $P = 0.004$).

4.7 However, not all our rivers are declining. Rivers such as the, Pohangina ($F = 0.06$, df = 1,5, $P = 0.81$, $R^2 = 0.01$,), and Makuri ($F = 2.88$, df = 1,4, $P = 0.16$ $R^2 = 0.27$,), remain stable, showing no significant upward or downward trends over time.

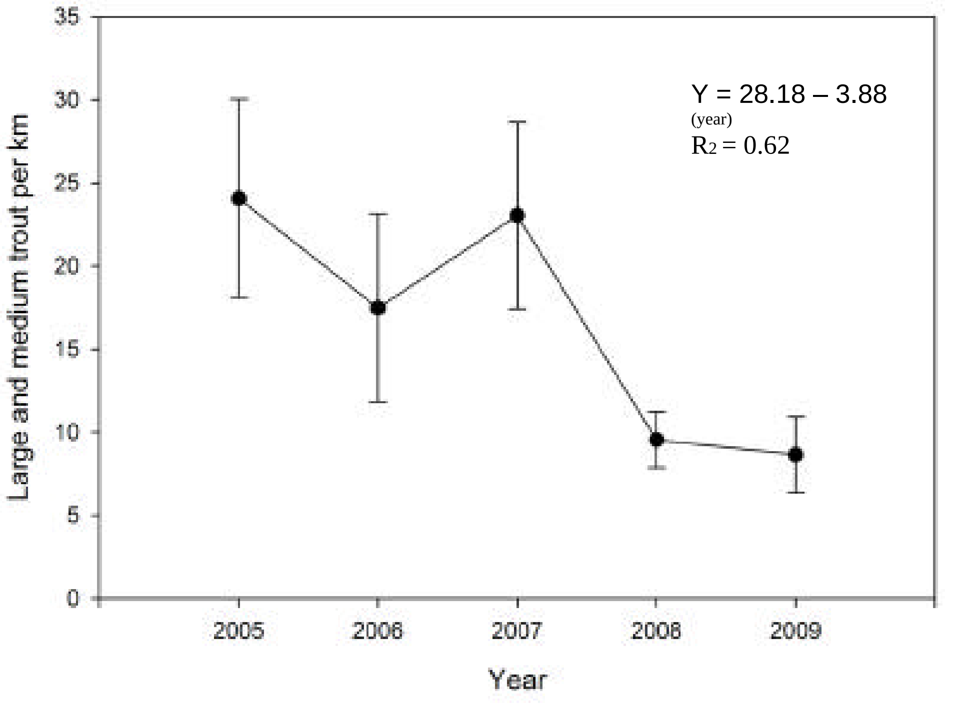

Figure 2. Cumulative assessment of the Wellington Fish and Game Trout Fishery

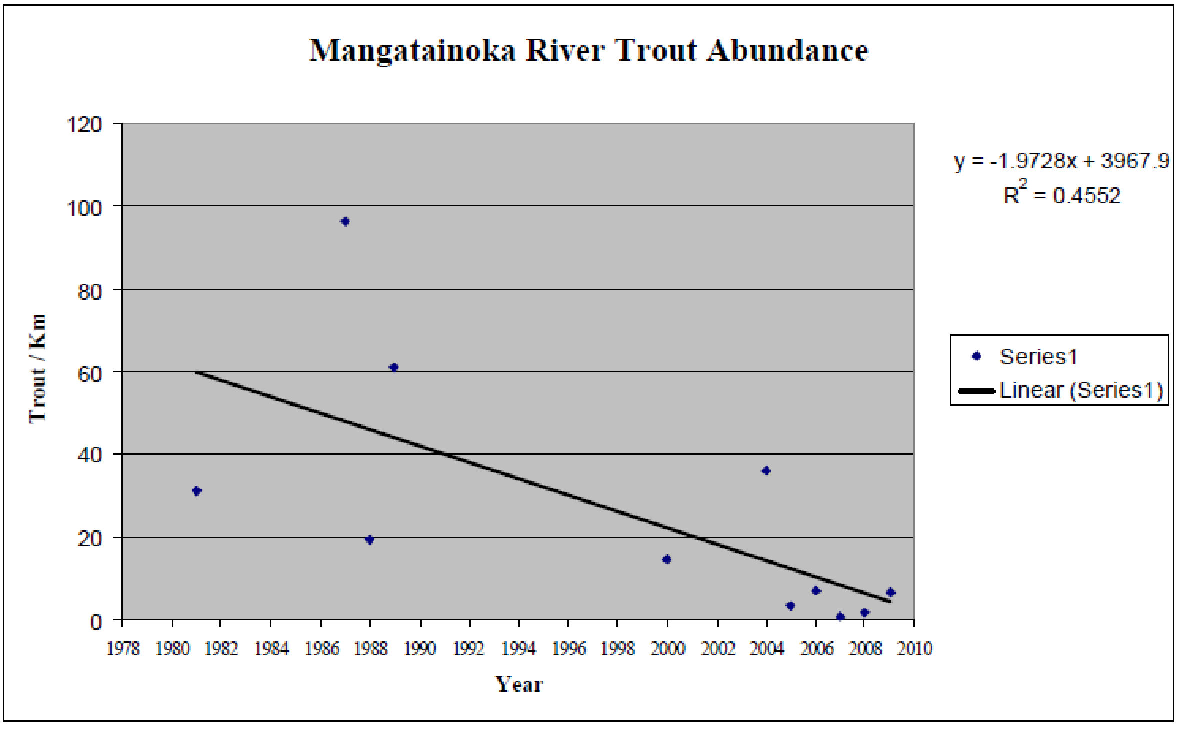

Figure 3. Mangatainoka River trout abundance, over time, as assessed by drift diving

4.8 Trout abundance in rivers such as the lower Rangitikei, and Manawatu, cannot be assessed by Drift Diving due to poor visibility. Cawthron is currently trailing new technology which may, in the future, enable turbid rivers to be assessed by sonar.

4.9 Results from the National Angling Survey show that angler use in the Rangitikei is remaining stable (~6060 for 2007/08 season, and ~5710 for the 1994/95 season) (Unwin, 2009), and angler use in the Manawatu also appears stable (~14220 angler days for the 2007/08 season, and ~11970 angler days for the 1994/95 season), with 90% of those angler days upstream from Palmerston North (Unwin, 2009), due to decreasing water quality downstream.

Conclusion

4.10 Wellington Fish and Game Regions trout fisheries are under threat, with many rivers showing declines in trout abundance. The once trophy fisheries which were protected under local water conservation notices are now struggling. Poor water quality from point and non point source pollution, low flows due to high abstraction volumes in some catchments, and the degradation of trout spawning habitat is significantly adversely impacting on the sustainability of our recreational fisheries and adversely impacting on our anglers recreational, intrinsic and amenity values. These issues are discussed further below.

5. FRAMEWORK OF THE ONE PLAN AND IDENTIFICATION OF VALUES

5.1 Based on solid science and backed by general community support Horizons has developed a new framework for their Regional Policy Statement and Plan. In recognition of the dynamic interlinked ecosystem processes functioning within the regions environment, Horizons has adopted an internationally endorsed, integrated catchment management approach. As discussed in the s42a officer planning reports (2009, TEB) this approach aims to address the four primary causes of environmental degradation in the region, which are: Surface Water Quality Degradation; Increasing Water Demand; Unsustainable Hill Country Land Use; and Threatened Biodiversity. The following evidence focuses on the issue of Water Quality Degradation, including habitat degradation of freshwater resources.

5.2 There is a substantial body of scientific evidence that supports the approach being taken in the One Plan as discussed in Dr Roygards s42a officers reports (2009, TEB). The framework set out in the One Plan is one that when read in its entirety, provides a clear link between the stated issues through to the objectives, policies and methods including rules. This approach provides a regionally relevant translation of Schedule 3. The establishment of numerical standards give effect to the narrative within the RMA. Freshwater values (as discussed by Dr Ausseil, and as contained within the s42a officers report of Ms McArthur, 2008, TEB) are attributed to Management zones and reaches, and numerical water quality and quantity standards are established by which to protect those values.

5.3 In giving effect to legislative directive, and in recognition of the regional importance of trout fisheries, Horizons included within the values framework of the One Plan, all known trout fishery rivers. Spawning habitats were identified, and the recreational trout fishery sites were classified as: Outstanding (I) for those rivers protected by National Water Conservation Notices; Regionally Significant (II) for those rivers protected by Local Water Conservation Notices, or offering similar levels of exceptional angling opportunity; or Other (I) for our locally significant fisheries. I support the identified trout fishery and spawning habitat information contained within the Proposed One Plan, and confirm it as accurate. I also support the contact recreation, aesthetic and riparian values.

6. REGIONALLY SIGNIFICANT ISSUE – WATER QUALITY AND AQUATIC ECOSYSTEM HEALTH

6.1 Horizons has presented a substantial amount of evidence in regards to the state of freshwater resources in the region, at both the council level hearings (2009, TEB), and also in further evidence to the court (Roygard *et al*, 2012a, Roygard *et al*, 2012b, Barton, 2012). In regards to the state of freshwater resources in the region, I support this evidence and their conclusions. As stated in section 6.2, under Issue 6-1 of the Proposed One Plan, the "*quality of most rivers and lakes in the Region has declined to the point that ecological values are compromised and contact recreation such as swimming is considered unsafe*" (POP section 6.2 Significant Resource Management Issues, Issue 6-, pg6-6, 2007). Non point source discharges (diffuse pollution) from agricultural land use, and Point source discharges of treated wastewater, are the primary causes for deteriorating water quality in the region, along with hill country erosion (Horizons Proposed One Plan, 2007).

6.2 Poor water quality is a concern to many people as discussed in the evidence of Dr Botha and Dr Marsh (2012), and disposal of wastes into water, and discharges of non point source contaminants, is becoming more and more unacceptable to the regional community. Poor water quality detracts from an anglers tangible and intangible amenity values, as well as posing a health hazard. Discharges of Point and non point sources of pollution to the regions streams and rivers have the potential to substantially alter conditions in the river causing ecosystem instability, reducing species diversity, and adversely impacting on the sustainability of trout populations. The impacts of non point and point source inputs of pollutants on freshwater ecosystems, including the regions recreational trout fisheries is discussed further in my evidence, and in the technical evidence of Associate Professor Death (2012), and Dr Ausseil (2012). I support this evidence.

6.3 As discussed by the technical evidence (Horizons s42a officer reports including Ms McArthur, 2009, Dr Young, 2009, Dr Biggs, 2009, Dr Quinn, 2009; and as discussed in the technical evidence of Associate Professor Death, 2012), few rivers are now safe to drink from directly, the middle and lower reaches of many rivers are unsafe to swim in because of bacterial contamination, or are unpleasant to swim in because of excessive periphyton growth; cyanobacteria growths, which can be toxic to people and animals, have been recorded at an increasing number of sites in the Region including the upper Manawatu, Mangatainoka, and Ohau Rivers. The lower reaches of many rivers have high concentrations of bacteria, nitrates, phosphates and sediment.

State of the Resource - Manawatu River and Trout Fishery Value

6.4 The Manawatu River is 235 km long and flows from the eastern side of the Ruahine and Tararua Ranges, west through the Manawatu Gorge to the Tasman Sea. The river drains a total catchment area of 5944 km^2, much of which has been developed from native forest to pasture, resulting in sparse riparian cover. The upper reaches of the Manawatu catchment support mainly hill country sheep and beef production, while the more gently rolling or flat land gives rise to intensive dairy farming.

6.5 Water quality is a major issue in the Manawatu River (McArthur, 2004, TEB), which is rated as one of the most polluted rivers in New Zealand. Water quality in the upper catchment is classed as '*moderately nutrient enriched'* but significantly degrades rapidly downstream (Fowler, & Henderson, 1999). The sources of this enrichment are diffuse nutrient runoff from agricultural land use (80% of DRP and 98% of SIN are non point sourced) (McArthur, 2009), urban sewage discharges and industrial wastewater discharges (McArthur, 2009). The water quality of the Manawatu is exacerbated during low flows by high rates of water abstraction, particularly in the upper catchment (Hurndell, 2009). Stock have access to a large proportion of the waterways and in conjunction with the lack of riparian cover cause direct adverse impacts on water quality through nutrient and sediment inputs in addition to direct stream bank and bed erosion, which impact on adult trout and trout spawning habitats. Periphyton and cyanobacteria proliferations are common, Ecoli standards breach safe contact recreation guidelines during low and high flows, and macroinvertebrate health is significantly compromised (McArthur, 2009).

6.6 Surveys of fish communities of the upper Manawatu tributaries found lower altitude sites are degraded with generally low to medium fish abundance when compared to the national average (Hamer & Lewis, 2004), with the near absence of migratory native fish (McArthur, 2009).

6.7 The Manawatu River is the most used fishery by anglers in the Wellington Fish and Game Region, rating higher than the Hutt, Ruamahanga and Rangitikei Rivers (Unwin, 2009). It supports a year round population of brown and rainbow trout, and offers exceptional close to home angling opportunity, with over 14220 angler visits recorded in the 2007/2008 National Angling Survey (Unwin, 2009). About 90% of those angler days are upstream of Palmerston North. Nationally it ranks 10th of all rivers fished excluding those inflowing to Lake Taupo.

6.8 Below the Tiraumea confluence the Proposed One Plan classifies the middle and lower Manawatu River as "*locally significant*". Progressive degradation of the Manawatu River, from point source and non point source discharges of pollutants, and high sediment loads, reduce its attraction to anglers, and impact on the trout fishery, as it travels down to the coast. Surveys by Barker and Forlong in 1985 (Barker & Forlong, 1985) found that over 50% of anglers who fished the Manawatu River, attributed "*poor water quality to adversely affected their fishing experience*". Since then the quality of the Manawatu River has continued to decline, and anglers recreational and amenity values with it. A survey by Taylor and Stancliff (2005) found that Wellington anglers considered "*pollution/poor water quality, and nuisance algae*" the most important factors contributing to them having a negative trout fishing experience below the gorge.

6.9 Despite the poor water quality, Fish and Game still actively promote the lower Manawatu Fishery down to Foxton Beach, noting in their Lower Manawatu River Fishery pamphlet (2006) that there are populations of "*Brown and Rainbow trout throughout, with perch around Palmerston North and downstream*". The lower and coastal Manawatu river offers tidal angling opportunity for sea run brown trout, which are common along the West Coast of New Zealand. Recent accounts by local anglers have reported good angling opportunity from Tokomaru down to the Opiki Bridge, with up to eight pound river run brown trout caught (Steve Brown, Manawatu Freshwater Anglers Club, *pers comm,* 2009.). Downstream from the Opiki bridge however, the angling recreational value decreases due to excessive '*growths of weed which choke the water, and pollution*" (Steve Brown, Manawatu Freshwater Anglers Club, *pers com,* 2009). During the WFGC annual gamebird count on the lower Manawatu River it was noted by our senior Officer Mr Steve Pilkington that "*the state of the water downstream from Opiki was disgusting. There were 3 dead cows in the river and on its banks, excessive growths of instream weed, the smell of the water was highly offensive, and the colour a deep turbid brown*" (Steve Pilkington, Wellington Fish and Game Field Officer, *pers comm*., 2009).

Figure 4. Lower Manawatu River below Opiki, showing discoloured water bank slumping and erosion (February 2009)

Figure 5. Manawatu River, below Opiki, showing stock grazing river banks, and stock caused erosion.

State of the Resource – Mangatainoka River and Trout Fishery Value

6.10 One of the Regions most highly valued trout fisheries, the Mangatainoka flows from the eastern Tararua Ranges in a north/ north east direction to join the Tiraumea just upstream from its confluence with the Manawatu River. The Mangatainoka River is ~70km long and has a catchment area of ~415km^2. Once extensively covered by native forest (Rimu, Rata, Matai, Totara, Tawa, and Kowhai) and scrub, now only ~18% remain. The Mangatainoka catchment is now predominately pasture with Sheep and beef as the main catchment land use (51%), followed by Dairy (28%) (McArthur, 2009). The Mangatainoka River is significantly impacted by non point and point source pollution, and high water abstraction.

6.11 Greater than 99% of SIN, and at high flows 84% of DRP is sourced from non point source pollution. Point source inputs of treated sewage from the two municipal waster discharges, Eketahuna STP (via the Makakahi) and Pahiatua STP combined with treated waste discharges from Fonterra Pahiatua and DB breweries, also make significant contributions to resource degradation, especially during low flows when they contribute the majority of DRP inputs. Both E.coli levels, and excessive periphyton growths, including cyanobacteria blooms increase as you move down the catchment, along with decreasing macroinvertebrate health. Over both the 2007/08 and 2008/09 summers extensive cyanobacteria blooms caused the Mangatainoka River at the Mangatainoka Reserve to be closed for recreational and amenity uses (McArthur, 2009).

6.12 Abstractions include both agricultural and town supply, with Eketahuna (via the Makakahi River), Pahiatua, and Pleckville taking for their rural supplies, and Fonterra and DB breweries taking for industrial uses. The combination of point and non point source pollution exacerbated by low flows during summer periods are having a significant detrimental impact on instream ecosystems including the Regionally Significant Trout fishery.

6.13 The Mangatainoka River was granted a Local Water Conservation Notice in 1991 under the Soil and Conservation Act 1967, in recognition of its regionally significant trout fishery values. Thought to be moderately remote from home, anglers rated the river a 4 out of 5, for ease of access, the large extent of fishable water, the quality and quantity of trout, solitude, and scenic value. Picnicking, swimming, and camping were also favored activities undertaken by our anglers. The Mangatainoka was rated as the third highest angling use river, after the Rangitikei and Manawatu Rivers over the 1994/95 angling season with ~ 3040 angler days (Unwin, 2009). Today the Mangatainoka is still rated as the regions third highest utilized angling river though angler days have dropped (~ 1990 angler days over the 2007/08 season) (Unwin, 2009).

6.14 The variability in the fishery and possible causes were noted in Mr Peter Taylor's hearing evidence for the Local Water Conservation Notice proceedings (1991), He stated that "*floods and fragile spawning conditions largely cause the observed variation in trout numbers, and prolific algal growths and flood control works (particularly in the past) suppress the fishery from time to time and in certain reaches*". He goes on to state that *"many tributary streams have been severely modified by channel straightening, have large cobbles replacing what were suitable spawning gravels, silt deposition, nutrient enrichment or suffer from stock trampling*" (Taylor, section 5.2, 1991). The trout fishery continues to decline, with results from the last drift dive counts of the trout population showing declines in the population from ~ 31 trout per km in 1981, and ~ 96 trout per km in 1987 to current levels of 7 trout per km in ($F = 7.52$, $df = 1,9$, $P = 0.02$).

6.15 The declines in trout population are attributed to the degradation of the resource including high inputs of both point and non point sources of pollution, low / stable flows during summer periods, causing excessive periphyton growths, lower DO levels, increased temperatures, and significant declines in macroinvertebrate health. These impacts, along with degradation of spawning habitats, through loss of riparian cover and direct stock access, which reduce the Natural Character of the river, contribute to declines in the health and sustainability of the Mangatainoka trout fishery. Historic high angler use may also have contributed to the current low numbers, though trout fisheries are renowned for jumping back rapidly with a successful spawning season. Over the last few years the daily bag limit has been set at 2 with a maximum size restriction, although many anglers prefer to catch and release.

State of the Resource – The Rangitikei River and its Trout Fishery

6.16 Included in Horizons Proposed One Plan in the "*Outstanding*" trout fishery class is the upper and middle Rangitikei, and the Manganui o te Ao Rivers and their tributaries. Theses sections of both these rivers, and their tributaries, are protected by National Water Conservation Orders in recognition of their nationally outstanding trout fishery and aesthetic values. The Manganui o te Ao falls within the Taranaki Fish and Game region, while the Rangitikei is managed by WFGC. The lower Rangitikei River is classified as "*Regionally Significant*" and the coastal Rangitikei is classified "*other*" in the Proposed One Plan.

6.17 The Rangitikei River flows 240km from its source in the Kaimanawa Mountains to the Tasman Sea, and attracts anglers from all over New Zealand as well as overseas. The Rangitikei headwater sports fishery has been rated one of the best backcountry fisheries in both New Zealand and the world (Taylor, 2001; Strickland and Hayes 2003). The entire Rangitikei River provides a diverse array of angling experiences, and angler opportunities for self sustaining populations of both Brown (*Salmo Trutta*) and Rainbow Trout (*Oncorhynchus mykiss*). The Rangitikei offers extensive areas of fishable water throughout its length. Easy access was characteristic of the middle and lower reaches (from Mangohane to Vinegar Hill), which are the most popular with over ~3690 angler visits for the 2007/08 season (Unwin, 2009).

6.18 The Rangitikei River passes through spectacular scrub covered bluffs, sheer papa cliffs, and gorges which create a dramatic setting. Anglers surveyed for satisfaction rated the Rangitikei 5 out of 5 due to its scenic beauty, relative solitude, and its angling opportunities. As a result picnicking, camping, and swimming were also popular recorded pastimes. Over the 2007/08 season the Rangitikei River attracted a total of ~6060 recorded angler days (Unwin, 2009). Within the Rangitikei catchment the recognized trout fisheries are the Rangitikei River mainstem, Otamateanui Stream (headwater tributary), Mangamaire River (headwater tributary), Whakarekou River and its two main tributaries the Maropea and Mangatera, the Hautapu River and the Kawahtau River and one of its tributaries, the Pourangaki.

6.19 Water quality in the Rangitikei River declines as you travel downstream, as discussed in the technical evidence of Associate Professor Death (2012), Dr Ausseil (2012), and as presented in the technical evidence of Horizons (McAthur, 2009, TEB, Roygard et al, 2012). The decline in water quality is attributable to diffuse pollution from agricultural land use, and point source discharges from sewage treatments plants (namely Bulls), and also discharges from Riverlands meat-works.

6.20 The convergence of the Hautapu River, which is degraded by the Taihapi STP discharge, and agricultural land use, along with the input of treated sewage from the Mangaweka STP contribute to the decline in the health of the middle Rangitikei river (McArthur, 2009). Five point source discharges of treated sewage into the lower Rangitikei River tributaries, along with inputs of treated sewage directly into the Rangitikei Mainstem along with Riverlands Manawatu meatworks discharge, causes degradation in the Coastal Rangitikei management zone (McArthur, 2009).

6.21 As discussed by Dr Ausseil (2012), and Associate Professor Death (2012) water quality in the Rangitikei River Tributaries (Porewa, Rangitawa, and Tutaenui streams) are significantly degraded by agricultural land use, and then further degraded by point source discharges of wastewater. Water chemistry, periphyton, and macroinvertebrate Schedule D standards are breached. The Porewa, stream is valued for trout spawning.

6.22 Excessive algal growths are caused by elevated levels of phosphorus and nitrogen, warm temperatures, and light. Algal blooms impact on both the health of the trout fishery, and recreational enjoyment of the angler. Periphyton growths can reduce over night dissolved oxygen levels which can impact on trout growth, reproductive rates, health and survival (Hay *et al*, 2006). Macroinvertebrate communities are altered to taxa that are less preferred as food items for trout, so again trout growth, health and sustainability are adversely affected.

6.23 Nutrient and contaminant enrichment can cause significant adverse impacts on the life supporting capacity of freshwater resources. High levels of suspended solids, nutrients, and associated increases in biological oxygen demand, adversely impact on aquatic communities, including trout populations and habitat..

6.24 Currently land use within the Rangitikei catchment is predominantly sheep and beef (66%) with Dairy the second most common (20%) (McArthur, 2009). Of 95 dairy discharge consent three of those are still to water (McArthur, 2009). As modelled by Dr Ausseil (2012) changes in land use with increases in intensive agriculture will continue to degrade the health of the Rangitikei River further. Further degradation is likely to impact on Nature based businesses within the catchment, on the life supporting capacity of the resource, the sustainability of the trout fishery, and the intrinsic and amenity values of recreational users. I support the re inclusion of the coastal Rangitikei back into Table 13.1 as a target management zone for agricultural land use.

7. WATER QUALITY REQUIREMENTS OF TROUT

7.1 Salmonids have high water quality and quantity requirements. The four major parameters for the protection of adult trout are water temperature, dissolved oxygen, water clarity/turbidity and food (Hay *et al* 2006). Because of their high water quality and flow requirements the Ministry for the Environment included trout in their analysis of potential indicators for freshwater (Froude, 1998).

7.2 Most salmonids are sit-and-wait predators that forage essentially on drifting prey. The abundance of which varies considerably between seasons, from day to day, and during the course of the day (Giroux *et al* 2000).

7.3 Research has shown that trout prefer to feed on taxa that inhabit high water quality streams (e.g Ephemoptera, Plecoptera and Trichoptera (EPT)), with large Trichoptera being the most highly preferred macroinvertebrate food item (Egglishaw 1967; Bisson 1978; Peddley and Jones 1978; Neveu 1981). These taxa are pollution sensitive and are found in the highest densities in riffle habitat (Shearer *et al*., 2002; Blakely and Harding 2005).

7.4 Adult caddisflies and Hydrobiosidae are typically the most preferred Trichoptera. These species generally have a low level of sclerotisation and inorganic material associated with them (cf stony cased caddisflies) which may account for their preference (Dedual and Collier 1995). Furthermore, adult caddisflies have a high fat content (Elliott 1991). Ephemeroptera are the next most highly selected invertebrate group (Dedual and Collier 1995). Caddisfly larva and mayfly nymphs were the main prey of brown and rainbow trout in the Mohaka system, with inputs of terrestrial insects increasing in importance in summer and stonefly nymphs in winter (McLennan and MacMillan 1984).

7.5 The presence and abundance of drifting adult aquatic insects on any given day is dependent on environmental conditions such as water volume, temperature, changes in light intensity, sedimentation and periphyton levels (Shearer *et al.,* 2002). Agricultural development of catchments is often associated with nutrient enrichment leading to progressive downstream increases in benthic algae, and a decrease in Ephemeroptera, Plecoptera and Trichoptera (EPT) scores and consequent changes in invertebrate community structure, which adversely impacts on the health and sustainability of trout populations (Fig. 6)

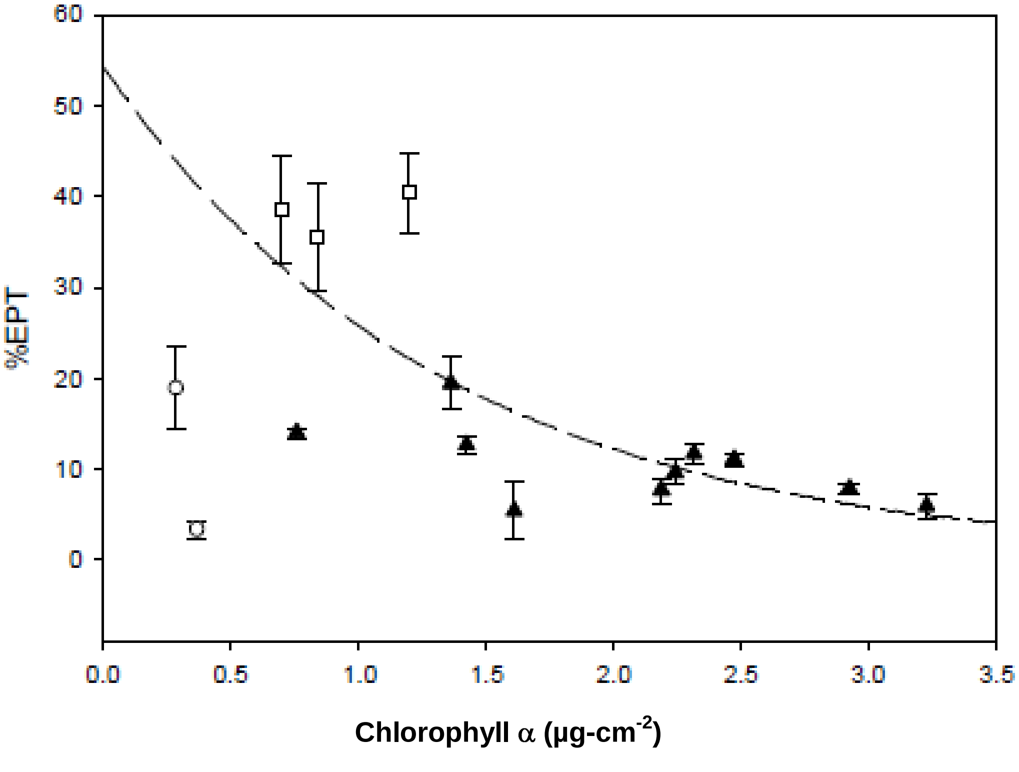

Figure 6. Drifting EPT caught as a function of periphyton biomass (From Death, 2008)

7.6 Hay and colleagues (2006) suggests that maintaining a MCI above 120 (indicative of clean water) for "*Regionally Significant Trout Fisheries*", or above 100 (indicative of possible mild pollution) for "*Other Trout Fisheries*" should be appropriate. This approach has been adopted in Schedule D, which I support.

7.7 Research has shown that the drift of the common mayfly *Deleatidium spp* (Ephemeroptera) is negatively related to chlorophyll a concentration (Shearer, 2003), which means that the ability of trout to feed on drifting Deleatidium is reduced when periphyton levels are high.

7.8 High nitrogen levels in the form of both ammonia and nitrate are also, detrimental to trout populations. Research has shown that high ammonia levels (2.55mg/L at pH7.52, and 1.44mg/L at pH8) kill salmonids eggs and increase adult mortality (USEPA, 1999). Maintaining concentrations of Ammonia below 10µg-N/L and Nitrogen levels low enough to reduce the likelihood of periphyton proliferation should be enough to avoid toxic effects on Salmonids (USEPA, 1999).

7.9 Dissolved Reactive Phosphorous (DRP) is most likely to indirectly affect trout, in combination with nitrogen by promoting proliferation of algae. Ensuring levels are maintained to reduce periphyton proliferation should be sufficient to protect trout fisheries.

7.10 Eutrophication or nutrient enrichment caused by elevations in both phosphorus and nitrogen, can lead to excessive periphyton growth, which can build up to high levels during periods of low/stable river flow (Elliott, 2000). Periphyton proliferation may reduce invertebrate diversity by smothering habitats, and increase diurnal variations in dissolved oxygen and pH, which can increase the potential for ammonia toxicity (Elliott, 2000, Quinn 2000, Allan 2004). All of these changes can lead to a shift in community composition from less tolerant, larger collector/browser mayflies, caddisflies and stoneflies to being dominated by more tolerant, smaller filter-feeding caddisflies, chironomids, collector/browser beetles, snails and oligochaete worms (Elliott, 2000). This may mean that invertebrate food for trout is less available or/ and of lower quality.

7.11 Decline in abundance of large, drifting invertebrates due to periphyton proliferation at low flow may further reduce drift rates, impacting on trout feeding ability. The consequences of reduced invertebrate drift rate at low flow, due to the reduced water velocity, on salmonid food requirements will be magnified by an interaction with elevated water temperature, as energy requirements of salmonids increase with water temperature (Hay *et al*, 2006, James et al., 2008).

7.12 Nusiance periphyton growths can adversely impact on the amenity and recreational angling values of freshwater resource, cause changes in water chemistry, and alter the composition and biomass of fish communities, and invertebrate communities (Biggs, 2000). Increased periphyton growths can result in decreases in Dissolved Oxygen (DO) as plants respire at night. Periphyton blooms and impacts on aquatic ecosystems is discussed further in the evidence of other witnesses, including Associate Professor Death and Dr Roygard.

7.13 Potential reductions in dissolved oxygen levels in relation to reduced flows and potential increases in periphyton growths could significantly increase trout mortality rates (Deans & Richardson, 1999). The dissolved oxygen requirements of salmonids are higher than for most other freshwater fishes, (Jowett, 1997), as discussed in section 7. Dissolved oxygen should be at least 80% saturation, however this will not be sufficient if temperature guidelines are exceeded(NIWA, 2005).

7.14 Maintaining Dissolved Oxygen levels equal to or greater than 80% saturation is recommended to maintain the health and sustainability of trout fisheries, especially during the spawning season. I note that in some of the regions trout spawning streams, eg the Raparapawai, Oruakeretaki, Tamaki, lower Kumeti, and Mangaterai Streams (which are identified as being priority catchments for managing agricultural land use), water quality standards are reduced, including a lower DO saturation standard (70%). As discussed by Dr Ausseil (2012), water quality in the Rangitikei River Tributaries (Porewa, Rangitawa, and Tutaenui streams) are significantly degraded by agricultural land use, and then further degraded by point source discharges of wastewater. Dissolved oxygen standards are breached both as a result of diffuse and point source pollution (ie they are breached upstream of the point source discharges, and downstream of the point source discharges). Breaches of DO standards constitute a significant adverse effect on the life supporting capacity of waterbody. The Porewa, stream is valued for trout spawning.

7.15 High levels of heavy metals have been found to have lethal effects on several freshwater invertebrates in New Zealand (Hickey and Clements 1998), including the cased caddis *Olinga feredayi*, the common mayfly *Deleatidium spp*, and the amphipod *Paracalliope fluviatilis* (Hickey 2000). Limiting toxicants to the 99% protection level as indicated in the ANZECC guidelines is recommended. 7.9 Nutrient enrichment (due to increases in DRP and SIN) cause increases in periphyton growth (discussed in Kate McArthur's Officers report), which can result in decreases in Dissolved Oxygen (DO) as the biological oxygen demand increases (BOD5). Dissolved Oxygen is essential for trout, which require higher levels (DO >80% saturation, >6mg/L and >9mg/L when spawning) than most other freshwater fish (Hay *et al*, 2006). As DO levels drop toward 5mg/L, growth rates, reproductive rates, health, and survival of trout are adversely affected (Hay *et al*, 2006). Dissolved Oxygen levels are also affected by temperature. Dissolved oxygen levels of 80% saturation, may not be sufficient if temperature guidelines are exceeded (NIWA, 2005).

7.16 Since trout are visual predators and drift feeding is the predominant foraging behaviour in most rivers (especially those of moderate to steep gradient), Increasing algal growth and decreasing water clarity will adversely affect the ability of trout to "*sight feed*" on high quality drifting macro-invertebrates such as EPT taxa (mayflies, stoneflies and caddisflies), as it will reduce their ability to detect and intercept drifting prey (Gregory & Northcote 1993). The strength of this effect depends on trout size and prey size, but will start to have an effect once water clarity drops below 4 m (Hayes, 2007). Generally maintaining clarity levels of 3.5m - 5m, as measured by black disk, are required to maintain reaction distances of drift feeding trout at appropriate levels (Hay *et al*, 2006).

7.17 Deposited sediment can also clog interstices of streambed substrates leading to a reduction in water exchange with surface waters and causing the interstitial layer to become oxygen depleted. Silt accumulation and these associated factors generally bring about a change in invertebrate communities, with a loss of stonefly and mayfly species, and an increase in densities of animals such as chironomids and oligochaetes (Suren, 2005), which adversely impact on trout feeding and hence the health and sustainability of trout fisheries. Mayfly nymphs and caddis larvae are adversely impacted by high sediment levels as they preferentially graze unsilted rather than silted periphyton (Suren, 2005; Waters, 1995).

7.18 High deposited sediment levels also adversely impact on trout spawning success by smothering the gravels, or interstitial spaces, and reducing the flow of water, and consequently dissolved oxygen to the eggs or alevins, and the removal of metabolic wastes. Associate Professor Death provides further evidence on the impacts of Deposited sediment on aquatic ecosystem health. I concur with his evidence and support his conclusions. Expert conferencing in regards to the inclusion of deposited sediment standards into Schedule D has been undertaken with the Regional Council. Agreement has been reached in regards to

7.19 The main concerns with water temperature are the effects of high temperatures on aquatic life. The productivity of a trout population will suffer as water temperature approaches and exceeds 19°C. Laboratory studies looking at the impacts of high temperatures on trout, have found that brown trout ceased feeding once temperatures climbed above 19 °C and that they would die if temperatures climbed above 25 °C for a sustained period (Elliott 1994). Trout deaths have been reported in New Zealand rivers when water temperatures have equalled or exceeded 26°C (Jowett 1997). Similarly, 50 % of *Deleatidum* mayflies will die after 4 days in water at 22.6 °C (Quinn *et al*. 1994). However, the thermal range for developing trout embryos, is much narrower. The preferred range for brown trout spawning is 3-20°C, with an optimum temperature of 10°C, and for hatching a preferred range of 2-11°C with a maximum of 20°C (Death, 2002; NIWA, 2005).

8. TROUT SPAWNING REQUIREMENTS

8.1 Trout populations living in rivers normally migrate upstream into smaller headwater tributaries to spawn (McDowell, 1990). In the Wellington Fish and Game region migration is generally around April/May depending on flow conditions, with peak spawning occurring June/July. Spawning takes place in swift flows over relatively stable gravels (up to 5cm in diameter) on a uniform area of bed. The female excavates a trough (also known as a '*redd*') laying eggs ~15cm deep in the gravels of the streambed often at the tail of a pool.

8.2 The female trout lays up to 2,000 – 3,000 eggs during the spawning season, which accounts for the rapid reinstatement of some trout fisheries following troughs in trout abundance. Approximately 1 – 6 egg pockets are contained per redd. The male fertilisers the eggs, and the female then excavates upstream. The dislodged material covers the eggs and if there is suitable area available this excavation can form another egg pocket.

8.3 After about 28 - 42 days the eggs hatch into alevins, which are 20 mm in length. The alevins remain in the gravels for a further 14 – 21 days to absorb the yolk sac attached to their stomachs. Incubation and emergence are temperature dependent. Successful egg incubation, and alevin development relies on cool water temperatures, adequate dissolved oxygen (>80% saturation), good percolation of water through the spawning gravels, at an adequate velocity (for oxygen delivery and removal of metabolic wastes) and a lack of sedimentation (McDowall 1990). The preferred temperature range for brown trout spawning is 3-20°C, with an optimum temperature of 10°C, and for hatching a preferred range of 2-11°C with a maximum of 20°C (NIWA, 2005). Too much fine material or sediment can stop the flow of water through the gravels, smothering the eggs, and suffocating the alevins. This is also a critical time when streambed disturbance is likely to have a detrimental effect on juvenile development and recruitment

8.4 The critical habitat requirements for successful spawning are:

- Headwater tributaries with reasonably stable winter flows
- Suitably sized gravels with little sediment deposition on the bed
- Low water temperatures
- Clean, sediment free water
- High oxygenation
- Undisturbed streambed

8.5 Salmon and trout fry and fingerling migration is significantly higher during freshes and high flows and occurs mostly during the night, and more so during moonless nights (Unwin, 1986; Davis and Unwin, 1989; Fox *et al.*, 2003). The majority of migrating juvenile salmon are encountered in the top 0.5 m of the water column (Glova and Boubée, 2002). Trout fry have a strong preference for bank side movement and keep to the edges of the main channels, near to the banks of the streams and rivers (Unwin, 1986; Hopkins and Unwin, 1987; Fox *et al.*, 2003; Unwin & Taylor, 2007). Fry feeding on small insects living in the streambed grow to fingerlings (~100mm) in the first year and generally live in shallower rocky margins of rivers. As they grow into adult fish, 2 – 3 years and 25 – 50cm in length, they move into water where depth provides them with protective cover or they seek out overhanging banks and vegetation in which to hide.

Figure 7. Spawning redd obvious in gravels of the Kahuterawa Stream. Approximately 100% periphyton cover (with the exception of the spawning redd in which periphyton has been dislodged), growths of filamentous algae present (July 2009).

Case study - Trout Spawning habitat and Agricultural land use

8.6 As part of WFGC statutory mandate under s26c of the Conservation Act (1987), WFGC undertakes spawning surveys to access the state of the regions trout fisheries.

8.7 In the Upper Manawatu Catchment the following Manawatu tributaries provide essential spawning habitat which is essential in sustaining the trout fishery: the Tamaki, Oruakeretaki, Raparapawai and Mangaatua Rivers. The Upper Manawatu catchment including these tributaries are identified in Horizons One Plan as being significantly impacted by non point source pollution from agricultural land use. Water quality issues are exasperated by high rates of abstraction, with the entire upper Manawatu Catchment being fully allocated, and a number of its tributaries eg Raparapawai over allocated. Water quality in the Tamaki is further degraded by the Dannevirke STP discharge.

8.8 The East Tamaki River (headwaters of the Tamaki) is rated as one of the highest spawning tributaries of the Manawatu Catchment. It provides excellent habitat, in regards to gravels, bed stability, and flows, though as with the other streams running through agricultural land it suffers from stock disturbance, and lack of riparian habitat. Water quality degrades as the East Tamaki flows downstream to join the Tamaki River. In early July (2005) Fish & Game officers undertook a spawning survey of the East Tamaki as far as the first riparian fence. The catchment is predominately sheep and beef with few land owners. There were more than 20 spawning redds identified and many adult fish. However the stream banks show signs of slumping from stock trampling and faecal matter was evident on the dry areas of streambed. The areas open to stock access exhibited lower numbers of spawning redds. In the report to Fonterra (Taylor, 2005) it was also stated that a "*fencing programme would likely enhance the spawning habitat further*".

Figure 7. East Tamaki River showing bank slumping, erosion, and lack of riparian fencing and habitat

8.9 Surveys in the Mangatainoka and tributaries showed that the Mangamaire, Makotukutuku, an unnamed tributary (on the Nireaha Plain), Mangaraupiu and Hukanui Streams all had good to fair spawning activity (2005). Surveys in the Mangatainoka have shown extensive use with historic counts of up to 24 and 42 redds counted in some of the mainstem sites (Taylor, 1989). However spawning surveys undertaken over the last 4 years have not shown any spawning activity. Degradation of spawning habitat has been noted, due to a lack of riparian vegetation, and stock access to a large proportion of many of the streams, causing bank collapse and degradation in water quality. Degradation of spawning habitat is likely to be one of the key factors contributing to the decline in the Mangatainoka Fishery.

8.10 Spawning surveys in the Makuri Stream River, identified the reach of the Makuri River from the gorge to its confluence with the Makuri-iti River as being very good trout spawning habitat with large numbers of spawning redds identified (12 – 20). Though again evidence of bank slumping and collapse along the banks of the Makuri mainstem were noted. Spawning surveys in the Makuri-iti identified it as fair in regards to spawning redds but lacking in riparian vegetation with a high degree of bank collapse.

8.11 A report to Fonterra (2005) entitled “Manawatu Catchment Trout Spawning Habitat Enhancement” stated that the “Makuri River from the upstream end of the gorge to the headwaters would benefit significantly from stock exclusion” (Taylor, 2005. The stable flow regime, high proportion of suitable gravel beds and lower degree of sinuosity when compared to smaller spawning streams make it an ideal candidate for fencing and for the second stage of a spawning habitat enhancement programme”. Such a project would have significant spawning and advocacy benefits.

8.12 The impacts of agriculture land use on trout spawning and fishery rivers needs to be urgently addressed. The protection of trout spawning habitats is essential to the sustainability of regional trout fisheries

Figure 8. Makuri Stream showing lack of riparian fencing, full stock access, and bank erosion (2005).

9. TROUT HABITAT REQUIREMENTS & THE IMPORTANCE OF MAINTAINING HEALTHY RIPARIAN MARGINS

9.1 Under part 2 (s6) of the Resource Management Act 1991 Regional Councils need to recognise and provide for: -as a "*matter of national importance*" the preservation of the **Natural Character** [own emphasis] of wetlands, and lakes and rivers and their margins (s6);

9.2 Natural character includes the morphological components of the environment that sustain healthy ecosystems. In the case of trout the important morphological components of natural character, include, but are not limited to: riparian habitat; instream habitat diversity including, the presence of riffle habitat to support healthy macroinvertebrate communities, leading into cool deep pools with riparian shading; suitable gravels to support spawning, juvenile rearing, and adult trout requirements; instream woody debris; and adequate flows and flow variability to sustain the health of the system eg limit excessive periphyton growths, maintain instream morphological diversity, and flood plain connection, and reduce sedimentation issues.

9.3 The favourite habitat for trout is generally larger streams in mountain areas with submerged rocks, undercut banks, and overhanging vegetation. However, trout occupy a variety of habitats from mountain streams to lowland rivers, and lakes, in New Zealand.

9.4 Information on habitat preferences for brown trout indicate that they prefer areas with gravel or coarser substrate, water depths greater than 0.6 m and water velocity between

0.3 0.6 m^3/s (Hayes & Jowett 1994). Similarly, studies on a variety of stream invertebrates that are commonly included in trout diets have shown that these invertebrates generally prefer areas with a substrate dominated by gravels, cobbles, and boulders, water depths between 0.1 - 0.8 m, and water velocities between 0.6 – 0.9 m^3/s (Waters 1976).

9.5 Naturally meandering channels are typified by having complex morphologies that produce eddies and areas of low velocity, which are key characteristics of any productive instream habitat. Diversity of depth, flow and substrate size through pool, riffle and run components, are essential in supporting trout throughout their life cycles.

9.6 The interchange between riffles and pools often provide the best spawning sites (Wesche 1985), providing good percolation of water through the spawning gravels, adequate velocity (for oxygen delivery and removal of metabolic wastes), and high levels of dissolved oxygen, all of which are essential for successful egg incubation (McDowall 1990).

9.7 Areas of low velocity act as refugia for many invertebrates during times of high flow. Pools also, provide deep cool water which are essential habitat for adult trout, providing space, shelter and food. They also act as essential areas of refuge during periods of low flow.

9.8 Natural streams usually support well vegetated riparian margins, and instream plant communities of algae and/or macrophytes. Both riparian and instream vegetation are important components of stream ecosystems and often provide food for invertebrates, shelter for fish (including trout), birds, and spawning sites for galaxiid fish. Both instream and riparian cover are also important for spawning adult, and newly hatched trout (Wesche 1985). Clearing riparian vegetation degrades instream habitat by removed a potentially important energy source and reducing physical habitat. The importance of maintaining riparian habitat is discussed is the technical evidence of Associate Professor Death, I concur with this evidence.

9.9 The interconnections between waterbodies are important for maintaining the resilience of the system. Smaller streams provide spawning and rearing habitat, while the main river sections provide good habitat for adult trout. Habitat with larger interstitial spaces, protective cover, or that is less impacted by floods will act as refuges during periods of high flow, while diversity of spawning habitats makes it unlikely that a flood or other disturbance will affect all recruitment areas. Free passage among the different waterbodies is required to maintain the resilience of the system

9.10 Trout migration is also impacted by reducing channel heterogeneity, and increasing sediment loads (McDowell, 1990). Although adult trout have established territories within suitable habitats, they undertake upstream and downstream migrations annually for spawning (McDowall 1990). If long lengths of a river do not provide resting sites during this migration, due to a lack of habitat diversity, increased water velocity, and habitat degradation from stock access, hey effectively become barriers to spawning migration and thereby adversely impact on the reproductive capacity of the population. The importance of instream migration (McDowall 1990) is often overlooked as a consideration for trout habitat.

9.11 Trout are especially sensitive to habitat change. They require cold well oxygenated water with low sedimentation levels, especially during the trout spawning period, where cold, well oxygenated water and gravels, and minimal sedimentation are essential to spawning success and alevin survival. Abundant pools (riffle pool components) are also vitally important as they not only offer adult trout habitat, and angling opportunity, they also provide essential resting sites for trout during migration.

9.12 Access of stock to waterbodies impact s on riparian habitat, and can have significant impacts on instream habitat. This is discussed in the evidence of Dr Ausseil (2012) and Associate Professor Death (2012). I concur with this evidence.

9.13 I support rules which ensure that cattle are excluded from waterbodies.

10. SCHEDULE D WATER QUALITY STANDARDS

10.1 The development of specific numerical standards for protecting instream values and evaluating POP objectives in regards to maintaining the life supporting capacity of freshwater resources is a positive and effective way of improving water management. These standards are a key component of the Proposed One Plan as they provide the basis for decision making in relation to matters on which the Regional Council has obligations under the Act.

10.2 The establishment of these standards is discussed in the s42a officers report of Ms McArthur, 2009, TEB), and in the technical evidence of Dr Ausseil. Associate Professor Death also provides further evidence in support of the Dissolved Reactive Phosphorus (DRP) and Soluble Inorganic Nitrogen (SIN) standards established in the Plan. I concur with these experts and support the established standards.

10.3 As discussed above and in the technical evidence of Associate Professor Death, and Dr Ausseil, deposited sediment is a significant contributor to the degraded state of some of the regions water ways. Elevated levels of deposited sediment impact on macroinvertebrate communities and the health and sustainability of the regions trout fishery. While the Proposed One Plan establishes non regulatory Whole Farm Plans to deal with the issue of land use practices, and hill country erosion, no numerical deposited standards were established. I consider this a serious weakness within the Proposed One Plan. Wellington Fish and Game has sought the inclusion of deposited sediment standards into Schedule D. I support this relief sought. As a result of discussions, Dr Ausseil, Associate Professor Death, Ms McArthur, and I have agreed upon a set of Deposited Sediment Standards which we believe are appropriate. These are included in the expert evidence of Associate Professor Death. I support these standards, and their inclusion into Schedule D.

11. IMPACTS OF AGRICULTUREAL LAND USES ON AQUATIC ECOSYSTEMS AND RECREATIONAL TROUT FISHERIES

11.1 Substantial evidence has been given on the state of freshwater resources in the region (Horizons officers, Dr Ausseil, 2012, Associate Professor Death, 2012), including the impacts agriculture land use activities are having through inputs of diffuse source pollution, and damage to riparian zones and stream banks. Research shows that many lowland streams and rivers within the region have low water quality and that these low water quality sites are more abundant in urban and intensively farmed agricultural areas.

11.2 There is an extensive body of research that changes in land use activities, particularly agricultural intensification, are resulting in a decline in Salmonid Sports fisheries worldwide (Peters, 1967; Jowett, 1992; Wiley, Kohler & Seelbaach, 1997; Borsuk *et al.*, 2006; Lobon-Cervia, 2009; Clews *et al.*, 2010) and in New Zealand. These changes include increased nutrient levels that may be directly toxic to eggs and young fish (Borsuk *et al.*, 2006) or result in excessive periphyton blooms (as discussed in the technical evidence put forward by the Horizons regional council, 2009, TEB, and in both my evidence and the evidence of Associate Professor Death, 2012), that change the chemical and physical characteristics of the habitat (e.g., pH, oxygen levels). I concur with this evidence.

11.3 Agricultural intensification also results in a change to the aquatic invertebrate communities from mayfly, stonefly and caddisfly dominated communities to worm, snail and midge dominated communities (Quinn *et al.*, 1997; Townsend *et al.*, 1997; Harding *et al.*, 1999; Townsend & Riley, 1999; Quinn, 2000; Allan, 2004; Greenwood *et al.*, 2012). This in turn can result in a reduction in the number and/or condition of trout as they must expend proportionally more of their energy searching for food than eating (Hayes, Stark & Shearer, 2000). I concur with this evidence.

11.4 Excessive algal growths are caused by elevated levels of phosphorus and nitrogen, warm temperatures, and light. Algal blooms impact on both the health of the trout fishery, and recreational enjoyment of the angler. Periphyton growths can reduce over night dissolved oxygen levels which can impact on trout growth, reproductive rates, health and survival (Hay *et al*, 2006). Macroinvertebrate communities are altered to taxa that are less preferred as food items for trout, so again trout growth, health and sustainability are adversely affected.

11.5 Research by Dr Joy (2009), investigating temporal changes of trout distributions over the past 37 years, has shown significant declines in trout presence, the steepest being over the last decade. This finding is supported by Wellington Fish and Games trout population monitoring, which shows that regional trout population numbers are trending downwards, with the greatest declines over the last 5 years.

11.6 Further investigation of these temporal trends, by Dr Joy, showed that trout absence or presence was strongly correlated to pastoral use, with strong negative relationships between trout presence and increasing proportions of pasture within a catchment ie increasing pasture cover was associated with declining trout populations. A strong positive relationship was found between trout presence and the proportion of catchment in native cover.

11.7 Recreational angling is impacted by declines in trout population numbers, declines in individual trout size, and decline in health. Angling also becomes difficult as lines get caught in algae and footing becomes precarious. Cyanobacteria blooms are also of concern and can be toxic. Anglers recreational amenity and intrinsic values become compromised.

11.8 Stock access to waterbodies, and loss of riparian habitats due to clearance for grazing of stock damage is also of significant concern. I have discussed the importance of riparian habitats to protect aquatic health, this is also discussed by Associate Professor, and Dr Ausseil. I support their evidence and conclusions.

11.9 A number of submitters have challenged the establishment of regulatory methods to control some farming practices in the Proposed One Plan. The issues of voluntary vs regulatory methods to control farming activities and the concerns of landowners are addressed in Mr Botha's evidence. Mr Botha goes on to support the approach of the Proposed One Plan.

11.10 Evidence clearly shows that agricultural land uses are significantly impacting on freshwater ecological integrity, which adversely impacts on the regions recreational trout fisheries and recreational angler values. The national trend towards continuing degradation of freshwater resources is applicable to the Horizons Region.

11.11 I support the approach established in the notified version of the One Plan to manage land use practices which are impacting on freshwater environments. Out of the 36 sites identified in the notified version of Table 13.1 which included the Coastal Rangitikei catchment, 50% of sites have essential trout spawning habitat, 27.8% of sites have "*regionally significant*" trout fisheries including the Mangatainoka and Makakahi (which have local water conservation notices), and 16.7% of sites have locally significant "*other*" trout fisheries.

12. REFERENCES

Acornley R. M. & Sear D. A. (1999) Sediment transport and siltation of brown trout (salmo trutta l.) spawning gravels in chalk streams. *Hydrological Processes,*13, 447-458

Allan J. D. (2004) Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology Evolution and Systematics,* 35, 257-284.

Argent D. G. & Flebbe P. A. (1999) Fine sediment effects on brook trout eggs in laboratory streams. *Fisheries Research,***39**, 253-262.

Arlinghaus, R., Mehner, T., & Cowx, I.G. (2002) Reconciling traditional inland fisheries management and sustainability in industralised countries, with emphasis on Europe. *Fish and Fisheries, 3. 261 –*
316.

Barker, R.J., & Forlong, R.(1985). A Survey of Angler Use and Opinion of the Manawatu River. Wellington Acclimatisation Society Tech Report.

Buchanan, I.M. 1992: Fisheries Resource Inventory: Mangahao River. Wellington Acclimatisation Society.

Borsuk M. E., Reichert P., Peter A., Schager E. & Burkhardt-Holm P. (2006) Assessing th decline of brown trout (salmo trutta) in swiss rivers using a bayesian probability network. *Ecological Modelling,***192**, 224-244.

Clews E., Durance I., Vaughan I. P. & Ormerod S. J. (2010) Juvenile salmonid populations in a temperate river system track synoptic trends in climate. *Global Change Biology,***16**, 3271-3283.

Collins A. L., Naden P. S., Sear D. A., Jones J. I., Foster I. D. L. & Morrow K. (2011) Sediment targets for informing river catchment management: International experience and prospects. *Hydrological Processes,***25**, 2112-2129

Cowx, I.G (2002). *Analysis of threats to freshwater fish conservation: past and present challenges*. Conservation of Freshwater Fish: Options for the Future. Oxford, Blackwell Science, pp 201 – 220.

Cowx , I.G., & Gerdeaux,D (2004) The effects of fisheries management practices on freshwater ecosystems. *Fisheries Management and Ecology, 11, 145 – 151*

Dean, T.L. and Richardson, J. 1999. *Responses of seven species of native freshwater fish and shrimp to low levels of dissolved oxygen*. New Zealand Journal of Marine and Freshwater Research 33: 99-106

Death R. G. (2008) Effects of floods on aquatic invertebrate communities. In *Aquatic insects: Challenges to populations* (ed. J. Lancaster & R. A. Briers), pp. 103-121. UK: CAB International

Death R. G. (2002) The effect of temperature and low flow on brown trout (*salmo trutta*): A literature review, pp. 19. Palmerston North: Massey University.

Death, R.G., McArthur, K.J., Pedley, R, Johnston, I, and Dewson, Z. (2002) River Health of the Manawatu-Wanganui Region: State of the Environment report 2002 –invertebrate and periphyton communities. Prepared for horizons.mw by Massey University.

Dedual M and Collier K.J. (1995). Aspects of juvenile rainbow trout (*Onchorhyncus mykiss*) diet in relation to food supply during summer in the lower Tongariro River, New Zealand. New Zealand Journal of Marine and Freshwater Research 29:381-391

Dewson Z. S., James A. B. W. & Death R. G. (2007) The influence of reduced flows on stream invertebrate individuals, populations and communities. *Journal of the North American Benthological Society,* 26, 401-415.

Elliott, J.M. (2000). *Pools as refugia for brown trout during two summer droughts: trout responses to thermal and oxygen stress*. Journal of Fish Biology 56: 938-948

Froude, V (1998) Environmental Performance Indicators: An analysis of Potential Indicators for Freshwater Biodiversity. MfE, Wellington. Technical Report No 48 Fowler, R.T. and Henderson, I.M. 1999: Biomonitoring survey for benthic invertebrates in the upper Manawatu River. A report prepared for horizons.mw. Massey University, Palmerston North, New Zealand. Report No. 99/INT/411.

Fox, S., Unwin, M. J. and Jellyman, D. (2003). The Migration of Brown Trout in the Rakaia River System. Report to Fish and Game. NIWA, Christchurch.

Fudge T. S., Wautier K. G., Evans R. E. & Palace V. P. (2008) Effect of different levels of fine-sediment loading on the escapement success of rainbow trout fry from artificial redds. *North American Journal of Fisheries Management,* **28**, 758-765.

Greenwood M. J., Harding J. S., Niyogi D. K. & McIntosh A. R. (2012) Improving the effectiveness of riparian management for aquatic invertebrates in a degraded agricultural landscape: Stream size and land-use legacies. *Journal of Applied Ecology,***49**, 213-222.

Giroux F, Ovidio M, Philippart JC and Baras E. 2000. Relationship between the drift of macroinvertebrates and the activity of brown trout in a small stream. Journal of Fish Biology 56: 12481257.

Hamer, M and Lewis, R. 2004: Fish Communities of the Upper Manawatu River Catchment Tributaries. *Report for Fish & Game NZ and horizons. Report No. 2004/INT/422.*

Hanrahan, T. P (2007). Bedform morphology of salmon spawning areas in a large gravel bed river.
Geomorphology, 86, 526 - 536

Harding J. S., Young R. G., Hayes J. W., Shearer K. A. & Stark J. D. (1999) Changes in agricultural intensity and river health along a river continuum. *Freshwater Biology,***42**, 345-357.

Hartman K. J. & Hakala J. F. (2006) Relationships between fine sediment and brook trout recruitment in forested headwater streams. *Journal of Freshwater Ecology,***21**, 215-230.

Hayes J. W., Stark J. D. & Shearer K. A. (2000) Development and test of a whole-lifetime foraging and bioenergetics grwoth model for drift-feeding brown trout. *Transactions of the American Fisheries Society,***129**, 315-332.

Hay, J., Hayes, J. and Young, R. (2006). Water quality guidelines to maintain trout fishery values. Prepared for Horizons Regional Council. *Cawthron Report No. 1205*.

Hay, J., Hayes, J., Young, R. (2006). Water Quality Guidelines to Protect Trout Fishery Values. *Cawthron Report No: 1205.*

Hayes J.W., Stark JD and Shearer KA. (2000). Development and test of a whole-lifetime foraging and bioenergetics growth model for drift-feeding brown trout*. Transactions of the American Fisheries Society 129: 315-332*

Henderson , R. (2003).The effect of TPD diversions on the hydrology of the Moawhango and Rangitikei Rivers. Prepared for ECNZ Thermal/Tongariro Generation Group. *NIWA Client report CHC98/75 v2.*

Herbst D. B., Bogan M. T., Roll S. K. & Safford H. D. (2012) Effects of livestock exclusion on in-stream habitat and benthic invertebrate assemblages in montane streams. *Freshwater Biology,***57**, 204-217

Horizons Regional Council (2004). Water Allocation Project Rangitikei River. *Report No. 2004/EXT/606)*

Horizons Regional Council (2000). Rangitikei River Scheme Review (No 3) *Final Report (Report No. 2000/EXT/397)*

Horizons (2000). Summary Report of Technical Studies on the Oroua River and Tributaries. *Report No: 20/EXT/412*

James A. B. W., Dewson Z. S. & Death R. G. (2008) The effect of experimental flow reductions on macroinvertebrate drift in natural and streamside channels. *River Research and Applications,* 24, 22-35.

Jellyman, P.G., & McIntosh, A.R (2008) The influence of habitat availability and adult density on non diadromous fry settlement in New Zealand. *Journal of Fish and Biology, 72, 143 – 156*.

Joy, M. (1998). Native Fish Diversity of the Oroua River and Tributaries: A contribution to the life supporting capacity of the Oroua River.

McArthur, K.J. (2004) The influence of land use on freshwater macroinvertebrate communities in the Manawatu-Wanganui Region, New Zealand. *Unpublished research report*

Jowett I. G. (1992) Models of the abundance of large brown trout in New Zealand rivers. *North American Journal of Fisheries Management,***12**, 417-432.

Kragt M. E. (2009) A beginners guide to bayesian network modelling for integrated catchment management. Australia: Landscape Logic.

Lobon-Cervia J. (2009) Recruitment as a driver of production dynamics in stream-resident brown trout (*salmo trutta*). *Freshwater Biology,***54**, 1692-1704.

McDowall, R.M. (1990) *New Zealand Freshwater Fishes: a natural history and guide.* Heinemann

Reed, Wellington.

McDowell, R. M. (1990). New Zealand Freshwater Fishes: A Natural History and Guide. Heinemann Reed. Auckland.

McLay CL. (1968). A study of drift in the Kakanui River, New Zealand. *Australian Journal of Marine and Freshwater Research 19: 139-148*

McLennan JA and MacMillan BWH. 1984. The food of rainbow and brown trout in the Mohaka and other rivers of Hawke's Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research*
18: 143-158.

NIWA. (2005). Moawhango River: quantification of the effect of increased residual flows and flushing flows on stream communities. *NIWA Client Report CHC2005-073.*

Peters J. C. (1967) Effects on a trout stream of sediment from agricultural practices. *Journal of Wildlife Management,* **31**, 805-&.

Puckridge, J. Sheldon, F. Walker, K. & Boulton. 1998. *Flow variability and the ecology of large rivers*. Marine and Freshwater Research. 49, 55-72

Quinn J. M. (2000) Effects of pastoral development. In *New zealand stream invertebrates: Ecology and implications for management* (ed. K. J. Collier & M. J. Winterbourn), pp. 208-229. Hamilton: New Zealand Limnological Society

Quinn J. M., Cooper A. B., Davies-Colley R. J., Rutherford J. C. & Williamson R. B. (1997) Land use effects on habitat, water quality, periphyton, and benthic invertebrates in waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research,* **31**, 579-597

Richardson, J. & Fuller, I. (2008). A Quantification of channel planform change on the lower Rangitikei River, New Zealand. Massey University, Palmerston North. *Report prepared for Fish and Game.*

Sagar PM and Glova GJ. (1992). Invertebrate drift in a large, braided New Zealand river. *Freshwater Biology 27:405-416*

Scheurer K., Alewell C., Banninger D. & Burkhardt-Holm P. (2009) Climate and land-use changes affecting river sediment and brown trout in alpine countries-a review. *Environmental Science and Pollution Research,* **16**, 232-242.

Shearer KA, Hayes J.W and Stark JD. (2002). Temporal and spatial quantification of aquatic invertebrate drift in the Maruia River, South Island, New Zealand. *New Zealand Journal of Marine and freshwater Research 36: 529-536*

Shearer KA, Stark JD, Hayes JW and Young RG.(2003). Relationships between drifting and benthic invertebrates in three New Zealand rivers: implications for drift-feeding fish. *New Zealand Journal of Marine and Freshwater Research 37: 809-820* Stark, J.D. (2008) Trends in river health of the Manawatu-Wanganui region 2008 with comments on the SOE biomonitoring programme. *Stark Environmental Report No. 2008-7 prepared for Horizons regional Council.*

Suren A. M. (2005) Effects of deposited sediment on patch selection by two grazing stream invertebrates. *Hydrobiologia,* 549, 205-218.

Suren A. M., Martin M. L. & Smith B. J. (2005) Short-term effects of high suspended sediments on six common new zealand stream invertebrates. *Hydrobiologia,* 548, 67-74.

Sternecker K. & Geist J. (2010) The effects of stream substratum composition on the emergence of salmonid fry. *Ecology of Freshwater Fish,* **19**, 537-544.

Suttle K. B., Power M. E., Levine J. M. & McNeely C. (2004) How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. *Ecological Applications,* **14**, 969-974.

Taylor, P. (2005). Manawatu Catchment Trout Spawning Habitat Enhancement: A proposal prepared for Fonterra Co-operative Ltd by Wellington Fish and Game and He Tini Awa Trust. Wellington Fish and Game. Palmerston North

Taylor, P.H., & Stancliff, A. (2005). A survey of angler satisfaction in the Wellington and Taranaki Fish and Game Regions. A report to Wellington Fish and Game Council and Taranaki Fish and Game Council.

Taylor, P.H. 1989: Fisheries Resource Inventory: Mangatainoka River. Wellington Acclimatisation Society.

Taylor, P.H. 1990: Fisheries Resource Inventory: Makuri River. Wellington Acclimatisation Society.

Teirney , L.D.; Jowett I.G. 1990. Trout abundance in New Zealand rivers. An assessment by drift diving. Chistchurch, MAF Fisheries. NZ Freshwater Fisheries Report 118. 31p.

Tonkin & Taylor Ltd. (1999). The Effects of Flow Regulation on the Ecology of the Moawhango River. *Report prepared for Genesis Power Ltd.*

Townsend C. R., Arbuckle C. J., Crowl T. A. & Scarsbrook M. R. (1997) The relationship between land-use and physicochemistry, food resources and macroinvertebrate communities in tributaries of the tarieri river, New Zealand: A hierarchically scaled approach. *Freshwater Biology,***37**, 177-191.

Townsend C. R. & Riley R. H. (1999) Assessment of river health: Accounting for perturbation pathways in physical and ecological space. *Freshwater Biology,***41**, 393-405.

Unwin, M. & Image, K (2003) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2001/02 National Angling Survey. *NIWA Client Report: CHC2003-114, Christchurch.*

Unwin, M.J & Image, K. (2009). Angler usage of lake and river fisheries managed by Fish and Game New Zealand: Results from the 2007/08 National Angler Survey. NIWA client report: CHC2003-114.

USEPA. (1999). 1999 update of ambient water quality criteria for ammonia. *Office of Water, U.S. Environmental Protection Agency, Washington D.C E.P.A-822-R-99-014.*

USEPA. (1999). 1999 update of ambient water quality criteria for ammonia. *Office of Water, U.S. Environmental Protection Agency, Washington D.C E.P.A-822-R-99-014.*

Viner (1987) Inland Waters of New Zealand. Taupo Research Laboratory Division of Marine and Freshwater Science.; DSIR, Wellington.

Ward, J.V., Tockner, K. (2001). Biodiversity: towards a unifying theme for river ecology. *Freshwater Biology, 46 (6), 807 - 819*

Waters T. F. (1995) Sediment in streams: Sources, biological effects, and control. *American Fisheries Society Monograph,* 7, 251.

Weithman, A.S. (1999) *Socio economic benefits of fisheries*. Inland Fisheries Management in North America. American Fisheries Society, USA, pp 193 - 213

Welcomme, R.L., & Naeve, H. (2001) An international symposium on Fisheries and Society. *Fisheries Management and Ecology, 8, 283 – 462*.

Wiley M. J., Kohler S. L. & Seelbaach P. W. (1997) Reconciling landscape and local views of aquatic communities: Lessons from michigan trout streams. *Freshwater Biology,* **37**, 133-148.