BEFORE THE INDEPENDENT HEARINGS PANELS APPOINTED TO HEAR AND MAKE RECOMMENDATIONS ON SUBMISSIONS AND FURTHER SUBMISSIONS ON PROPOSED PLAN CHANGE 1 TO THE NATURAL RESOURCES PLAN FOR THE WELLINGTON REGION

UNDER	the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	of Hearing of Submissions and Further Submissions on Proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region under Schedule 1 of the Act

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STATEMENT OF EVIDENCE OF JAMES MITCHELL BLYTH

ON BEHALF OF GREATER WELLINGTON REGIONAL COUNCIL

SEDIMENT FROM PASTURE AND FORESTRY – TECHNICAL EVIDENCE

HEARING STREAM 3 – RURAL LAND USE ACTIVITIES, FORESTRY INCLUDING VEGETATION CLEARANCE AND EARTHWORKS

15 APRIL 2025

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INTRODUCTION

1 My full name is James Mitchell Blyth. I am a Director and Water Scientist at Collaborations.

2 I have undertaken a high-level review of submissions relevant to Hearing Stream 3 (HS3); Rural land use activities, Forestry including vegetation clearance and Earthworks.

3 I have prepared this statement of evidence on behalf of Greater Wellington Regional Council (**the Council**) in respect of technical matters arising from the submissions and further submissions Proposed Change 1 to the Natural Resources Plan for the Wellington Region (**PC1**).

4 Specifically, this statement of evidence relates to the matters in the Section 42A Reports – Rural Land Use and Vegetation Clearance and Forestry.

QUALIFICATIONS

5 I hold a Master of Science degree (**MSc**) with first class honours from the University of Waikato.

6 I am a Certified Environmental Practitioner (**CEnvP**) under the Environmental Institute of Australia and New Zealand (**EIANZ**).

7 I am a member of New Zealand Freshwater Sciences Society.

8 I have 15 years' experience at roles within regional councils, industry (mining) and consulting, and have worked internationally. My experience covers a range of water sciences, including sediment and erosion, water quality, water resources, hydrology, hydraulics and wetlands. Throughout my career I have been involved in numerous water balance and catchment hydrological and water quality models. While working overseas in environmental and mine water management, I was a technical consulting lead in hydrological and water balance modelling, and worked on models and trained staff in Africa, Canada, Laos, Thailand and Australia. Prior to joining Collaborations, I was the New Zealand lead for integrated catchment modelling at Jacobs New Zealand.

9 I have been involved in all four Whaitua processes the Council has run to date, and most recently was a technical advisor as part of the Council's project team for Te Whanganui-a-Tara (**TWT**) Whaitua. I was involved in co-developing the catchment water quality models in Ruamāhanga Whaitua, and project managing Te Awarua-o-Porirua (**TAoP**) Whaitua

catchment water quality modelling. These detailed models attempted to represent the current landuse, catchments, historical climate and streamflow in order to predict the movement of contaminants from source (i.e headwaters) to sink (rivers, lakes or the coast), and how effective landuse mitigations could be on these contaminants at scale.

10 My experience includes preparing evidence for the High Court, expert conferencing, and evidence at council-level hearings and Environment Court cases.

CODE OF CONDUCT

11 I have read the Code of Conduct for Expert Witnesses set out in the Environment Court's Practice Note 2023 (Part 9). I have complied with the Code of Conduct in preparing this evidence. My experience and qualifications are set out above. Except where I state I rely on the evidence of another person, I confirm that the issues addressed in this evidence are within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

SCOPE OF EVIDENCE

12 My evidence covers the following topics:

12.1 The sediment contributions from farming (pastoral) and plantation forestry over the long term (a reflection on national literature).

12.2 An understanding of the current visual clarity states of catchments with high proportions of those landuses within PC1.

SEDIMENT CONTRIBUTIONS FROM PASTORAL FARMING AND PLANTATION FORESTRY

13 Sediment generation in the PC1 area can occur from a range of erosion processes, primarily streambank and gully erosion, surface (or surficial) and landsliding. Erosion risk mapping[1] of some of these processes was undertaken to support the Councils land management teams and the plan change process, focussing on identifying higher risk areas of potential anthropogenic sources of sediment that may contribute to increased suspended sediment loads, which in results in reduced visual clarity[2]. The mapping process and refinement to ‘potential erosion risk’ maps has been covered in evidence by my colleague Mr Thomas Nation[3].

14 Visual clarity is a measurement used to determine the suspended fine sediment attribute state in the NPS-FM (2020) based on a sediment class. Median State of Environment (SOE)

monitoring data used to estimate the current state (approximately 5-years of records) that falls below national bottom line would indicate a high potential impact on instream ecology by suspended sediment.

15 There are six Target Attribute Sites (**TAS**) identified in PC1 that require reductions in their suspended fine sediment load[1] to meet either the national bottom line for visual clarity or targets recommended by the Whaitua Committee, as described in Blyth (2025)[2].

16 When considering anthropogenic sources of sediment in the rural environment, the primary landuse activities are pastoral farming and plantation forestry. There is also an increasing amount of land likely being converted to permanent/continuous cover carbon forestry, however, the extent of this landuse change is unknown as this has otherwise been occurring as a permitted activity.

17 My evidence does not cover the specific management policies or rules in PC1 or the benefits of different landuses either economically, socially or environmentally (for example, stream shading under mature pine forests); instead, this evidence provides context on sediment generation of the above landuses for consideration by the Hearing Panels as requested by the Council.

18 Generally, when comparing sediment generation of pastoral versus plantation forestry landuses, the majority of New Zealand studies show that over the long-term pasture will deliver more sediment than plantation forestry. This is primarily driven by the lack of woody vegetation cover that when present, has the effect of stabilising soils, canopy interception of rainfall and reduced infiltration to soils during storm events[4].

19 However, while plantation forestry is highly effective at reducing sediment when canopy closure is achieved (year 8 to approximately year 28; an estimate of harvest age), there are noticeable risk periods[5] where this landuse activity will generate sediment (potentially greater than pasture), primarily relating to the establishment of roads and infrastructure[6], harvest operations and the period following replanting prior to canopy closure (up to 8 years).

20 The following paragraphs will provide further evidence from New Zealand studies, including paired catchment studies on sediment contributions and erosion risk relative to different landuses.

[1] From their baseline state as defined in the NPS-FM 2020.

21 I will focus on plantation forestry landuse compared against pastoral landuse. As permanent/continuous cover forests are unlikely to be harvested, they are considered to have similar long term sediment generation rates as native forests once mature. An example of this is presented in **Figure 1** below, which shows the benefits of maturing pine (>8 years) and native forest with canopy closure and root establishment based on a study of landsliding in Gisborne Region following an extreme event; Cyclone Bola in 1988[7]. This study found closed canopy forest was 16 times less susceptible to landsliding than those under pasture or young pine trees (<6 years) and ~4 times less than regenerating scrub and 6-8 year old pine trees[7].

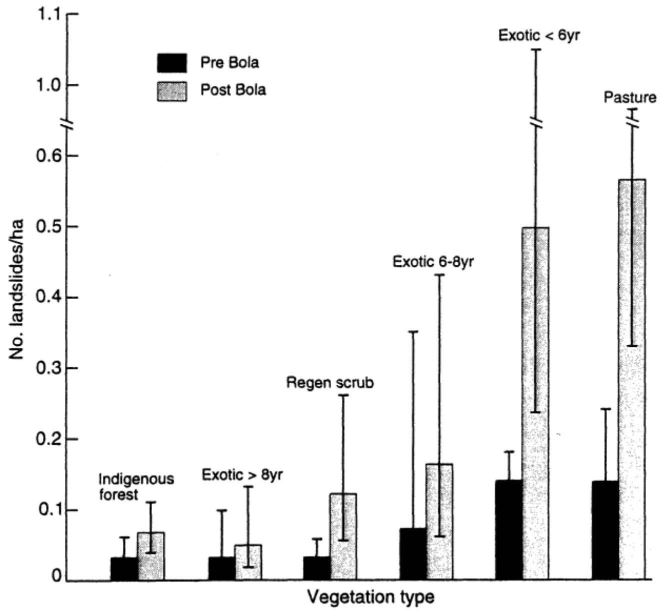

Figure 1: Pre and Post Cyclone Bola landslide densities for a range of vegetation types with 95% confidence intervals plotted as error bars (Marden and Rowan 1994)[7].

22 Native forests, mature plantation forest and shrubland can reduce erosion by up to 90% when compared to pasture (Drewry, Phillips and Graham 2023)[8]. Estimates of erosion rates in North Island hill country from pastoral land were 8-17 times greater than native forest[8], and in the long term NIWA **Whatawhata Integrated Catchment Management (ICM) Project** in the Waikato Region a pastoral stream delivered ~3 times the sediment load as a native podocarp catchment, with the former also prone to landsliding under extreme rainfall events (**Figure 2**). This native catchment had consistently higher water clarity, lower temperatures and nutrient concentrations (except phosphorus) than the neighbouring pastoral and pine catchments (Quinn and Stroud 2002; Hughes *et al*. 2022)[9,10].

Figure 2: Pastoral shallow landslides following a 2007 storm event in the Whatawhata ICM project site[10]

23 **Figure 1** and **Figure 2** are supported by a comprehensive review of the performance of erosion and sediment control techniques in New Zealand in Drewry, Phillips and Graham (2023)[8]; Phillips, Basher and Spiekermann (2020)[11] and Basher *et al.* (2018)[12]. These reviews found that:

23.1 Closed canopy woody vegetation cover (plantation forestry >8 years old and scrub, including native forest) resulted in 70-90% reductions in landsliding density or volume when compared to pasture.

23.2 Sediment loads increase from forestry activities during road construction and harvest operations, and post-harvest/replanting. Young pines (i.e.<6-8 years) yield similar sediment to pasture, although post harvest, sediment loads increase to be greater than pasture.

23.3 Mature, closed-canopy indigenous or plantation forestry also typically reduce sediment yield by up to 90% compared to pasture catchments.

23.4 Earthflow movement (not known to be present in the PC1 area) in plantation forestry were reduced by an order of magnitude or greater when compared to pasture.

23.5 Stabilisation of gully erosion was highly dependent on the size of the gully and shape, with an 80% chance of stabilising gullies <1 ha under plantation forestry, and little chance of success for actively eroding gullies >10 ha.

23.6 Streambank erosion was reduced by ~50% through riparian management. This reduction is variable in plantation forestry, depending on the ground and riparian cover along the streambank and previous landuse (see paragraph 25).

24 The risk period following harvest as presented in **Figure 3** is also supported by good practice guidelines (Eastland Wood Council 2022[13]) in the forestry industry.

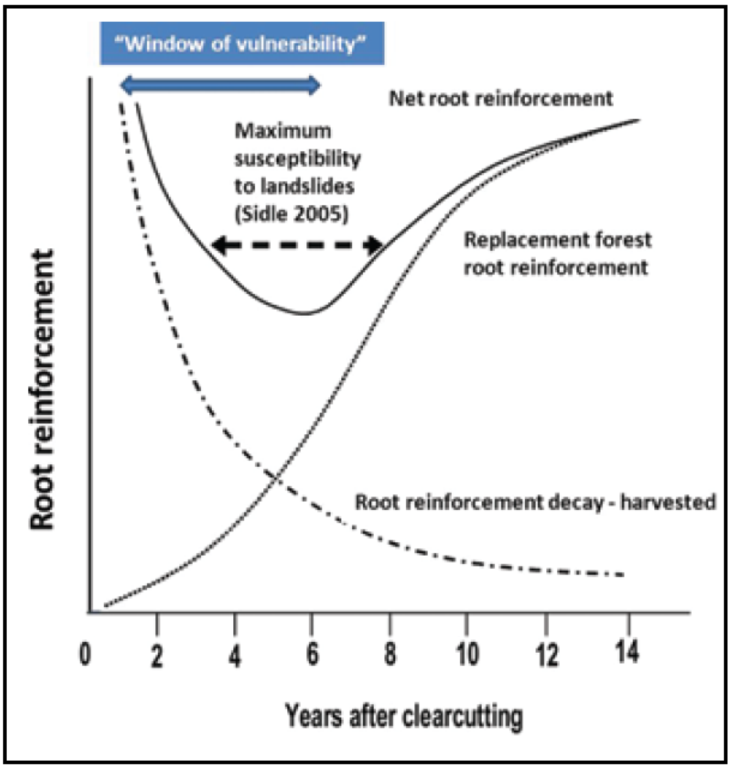

Figure 3: Change in root strength following harvest and period of vulnerability, as presented in Phillips et al. (2012)[4] and reproduced in Eastland Wood Council (2022)[13].

25 Erosion rates from different landuses will, however, be naturally variable depending on the slope, climate, and geology of the catchment being considered and connectivity of eroded sediment to a stream. The **Whatawhata ICM project** [9, 10] showed that a small (~11 ha) mixed mature pine forest (55% pine, 45% regenerating scrub/native) produced two times greater suspended sediment load than neighbouring pasture catchments (49-95 ha). This is contrary to the majority of New Zealand studies. The reason suggested by authors (Quinn and Stroud 2002)[9] for greater sediment loads from this pine catchment was due to erosion of sediment built up within the stream channel during the catchments previous

pastoral phase, prior to being converted into plantation forestry. Shading of the stream by forestry resulted in grass die back, and increased channel erosion even 23-28 years post planting, as the channel width doubled to resemble something closer to a natural stream.

26 Recent summaries (Hughes *et al.* 2022)[10] of the long-term findings in **Whatawhata ICM project** (relative to sediment) were consistent with Quinn and Stroud (2002)[9] that loads were lower in native catchments than a mixed pastoral/plantation forest catchment. However, in a pastoral catchment converted entirely to plantation forest, there was only a small improvement in visual clarity over the long term despite canopy closure being achieved, with authors aligning this with findings presented in paragraph25. No harvest cycles have been monitored in this study.

27 Plantation forest (under canopy closure) has the potential to reduce streambank erosion in the long term, driven by hydrological changes. Where pasture catchments have been converted to plantation forests, annual water yield can be reduced by 30-50% at approximately year 8, mainly through evapotranspiration and canopy interception. This also reduces peak flows by up to 50% out of the catchment over the non-harvest cycle (Fahey 1994; Davie & Fahey 2004)[14, 15] and therefore, the erosive nature of floods would reduce.

27.1 The benefits of this in relation to streambank erosion will depend on the volume of sediment entrained along the stream corridor prior to landuse conversion, the riparian buffer width (setback distance) established during planting and the extent of natural riparian vegetation growth under the forest canopy to stabilise the streambank. These attributes will be variable across all forest catchments. It is possible that plantation forests on second rotations would have reached an equilibrium for streambank erosion (see paragraph 25), however, limited studies are available to confirm this.

28 When considering the change in water yield post-harvest, a harvested plantation forestry catchments' peak flow during floods can increase, resulting in greater risk of erosion. Fahey (1994)[14] showed in two small forested catchments that clear-felled 83-94% of the forestry canopy, a 60-80% increase in annual water yield was observed for ~5 years after clear felling (until the new crop established) and peak flows also increased for a range of storm sizes. This increase in water yield and flood flows is highly dependent on the harvested area as a proportion of the total forest and catchment area[14], where large catchments (i.e. > 1000 ha) with forestry blocks in rotation may have only a small

hydrological change at the most downstream monitoring point, but greater effects in localised tributaries.

29 A well-known paired catchment study in the Hawke's Bay (the **Pakuratahi Land Use Study**) compared two catchments <1000 ha; the Tamingimingi (pasture) and the Pakuratahi (plantation pine forest) in relation to their water yields and sediment generation over a 12-year period pre harvest, road development, logging and post-harvest (Eyles and Fahey 2006)[16]. This study is summarised as follows:

29.1 Pre harvest annual water yields were 6% lower in the plantation forestry catchment, which had mature pines >20 years old. This period also resulted in suspended sediment yields ~four times greater from the pastoral land than the plantation forestry.

29.2 During and post harvest, annual water yields from the harvested plantation forestry catchment exceeded the pastoral catchment by ~22%, but this declined to within 5% ~6 years later after replanting. Erosion loss rates 'flipped', with the harvested catchment generating ~three times the sediment load than the pastoral catchment for a period of ~2 years.

29.3 Rapid replanting following harvest and adoption of best management practices including regular maintenance and improvement of roads and infrastructure resulted in significant reductions (and reversal) in erosion from the forested catchment ~2-3 years post-harvest, with sediment generation out of the pastoral catchment four times higher.

29.4 Woody debris post harvest helped trap sediment and resulted in higher streambed levels, which encouraged vegetation growth along stream channels. Storm events observed over this 12-year study had the greatest impact on Tamingimingi (pastoral) catchment with more streambank erosion observed.

29.5 It is worth noting that the harvest period of this study (Dec 1997 to October 1999) coincided with a significant drought that resulted in a number of summer and autumn months in 1998 receiving up to 92% lower rainfall than expected, although this was offset by three months of above average rainfall through the winter of 1998. A lack of significant storms from July to December of 1998 (year 1 of harvest), indicates that the assessment of the harvest period of this study may have benefitted from climatic events, and that sediment loads would have increased if storms and annual rainfall had tended towards or above the long-term average. This highlights the 'risk' period during harvest cycles which is strongly associated with climate/storm events over that timeframe[5].

30 A modern plantation forestry study with relevance to this evidence (Phillips *et al.* 2024)[17] assessed the post-harvest window of vulnerability (**Figure 3**) to shallow landsliding in Tolaga Bay, Marlborough and Tasman regions. This detailed assessment encompassed 0.5m resolution orthorectified satellite imagery overlaid with geological maps and a Digital Elevation Model (DEM) at 1m resolution on harvested forestry blocks of <6 years old, that had been subject to significant rain events in 2018 or 2021 (>200 mm in 24 hours, such as Cyclone Gita). They considered this assessment as a 'worst-case scenario'. The authors mapped each individual shallow landslide, assessed landslide densities (no. per km^2) in different forestry blocks and developed a model that evaluated ~23 variables (such as post-harvest block age and mean slope) relevance to predicting landsliding. Significant findings include:

30.1 Most shallow landslides occurred on general harvest/clear cut areas. Approximately 22% of all landslides were connected to infrastructure, such as roads, across the five forestry blocks in different regions, with no consistent correlation to harvest age. This indicates these areas may remain vulnerable regardless of the replanted forests age, noting the authors did not consider infrastructure risk for older, mature forests as part of the study.

30.2 Landslide density was greatest for 1–4 years post-harvest, averaging 272 per km^2 (see **Figure 4**). After five years post-harvest, landslide density declined markedly to ~93 per km^2, and by year six, ~46 per km^2. This indicates the highest risk period (years 1 to 4 post-harvest) had ~3 and 6 times greater landslide density than at years five and six, respectively. Densities were greater in Tolaga Bay mudstones/siltstones (~294 per km^2) than in the Marlborough Schists (32-211 per km^2). There was no comparison to landslides in mature forest in this study (i.e. pre-harvest), so >6 years would be the appropriate proxy.

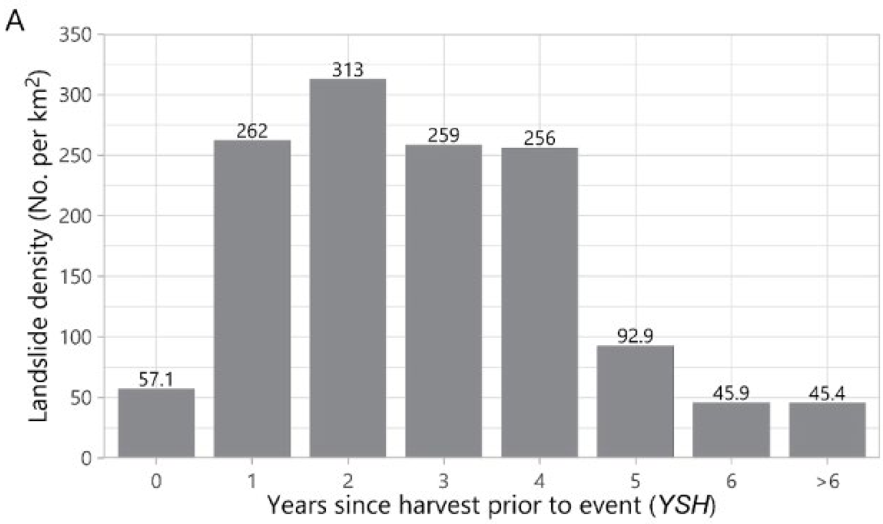

Figure 4: Landslide densities as an average across five blocks in three study areas (Phillips et al. 2024)[17].

30.3 The total proportion of landslides that delivered sediment to freshwater environments via streams, gullies or ephemeral channels (i.e. the stream delivery ratio, or SDR) averaged ~50% across all regions (varying from 35 to 73%).

30.4 Post-harvest age, geology and mean slope where amongst the most influential parameters in their landsliding predictive model. However, the authors noted the regression model could only predict ~55% of the variability in landsliding, a 'satisfactory' performance in respect to modelling guidelines. They latter state (page 11, p1) "*landslide science is not advanced enough to predict with certainty where in the landscape a landslide will occur, under what specific rainfall conditions, and when. Landslide susceptibility modelling can help determine areas of higher or lower susceptibility but not the exact location of future failures. Improvements in landslide susceptibility modelling, particularly at higher spatial resolutions, should help forest managers determine where to focus mitigation measures (if these can be implemented) or assist in future land use decisions such as retirement or transitioning to a permanent forest cover*"

31 When considering the relevance of the Phillips *et al.* (2024)[17] paper to Wellington Region, I have reviewed the predominant rock types of the studied forest areas and compared this to Dymond and Shepherds (2023)[18] **Highly Erodible Land** update, which details the slope thresholds at which that geology and terrain has a **high risk** of landsliding if there was no woody vegetation cover:

31.1 Marlborough forestry blocks[17] were considered hilly steeplands on weathered hard schist and greywacke, with a landsliding slope threshold of 28 degrees[18].

31.2 Tasman forestry blocks[17] were considered hilly steeplands on weathered coarse grain igneous rocks, with a landsliding slope threshold of 24 degrees[18].

31.3 Tolaga Bay forestry blocks[17] were considered hilly steeplands on weak sedimentary mudstone, siltstone and sandstone, with a landsliding slope threshold of 24-28 degrees[18].

31.4 Wellington region (PC1 area) with forestry could also be considered a mixture of hilly steeplands and mountain steeplands and upland hills. The primary rock type is greywacke (sandstone/mudstone), of varying states of weathering (unweathered to highly weathered) and can be crushed/fractured depending on proximity to fault lines. This would fit within a 24-28 degree landsliding slope threshold, but potentially up to a 45 degree slope threshold depending on the geological condition (i.e. unweathered greywacke with limited faulting)[18]. Subsequently, the landslide slope susceptibility may be variable or lower than the forestry blocks assessed in Phillips *et al.* (2024)[17] and we could therefore expect a lower landslide density within PC1 than presented in Figure 4, but likely the same relative difference (i.e. six times the landslide density for years 1-4 post harvest).

32 Other papers that support the contributions of sediment from pasture and forestry are:

32.1 A land cover disturbance study in the large (264 km^2) Hoteo catchment (north of Auckland) correlated landuse change and disturbance through remote (spatial analysis) aligned with water quality monitoring data (Kamarinas *et al.* 2016)[19]. This showed during forest harvest and recovery phases, exotic forests were the dominant disturbance and contributor to water quality declines, being up to five times the area of grassland disturbance; while after recovery, grasslands assumed the dominant role, for up to 16 times the area of forest disturbance. The area of the Hoteo catchment disturbed annually from forest harvest averaged 1,972 ha over a 13 year study period (7.3%)[19].

32.2 Basher *et al.* (2011)[20] assessed the change in suspended sediment yield at seven sites in the Motueka catchment (Tasman Region). Forest harvesting produced on average, a five-fold increase in sediment yield, and returned to pre-harvest sediment yields within ~3-5 years. Storms were the dominant driver of sediment delivery, with *five storms* carrying between 58-89% of the total load measured over the monitoring period (4-6 years) across four primary monitoring sites. These catchments were mixed landuses, including native, plantation forestry and pastoral, so it would be reasonable to assume that post harvest sediment load could be higher in a catchment dominated by plantation forest.

32.3 Urlich (2015)[21] provided a detailed report in Marlborough Sounds on options to mitigate the fine suspended sediment loss through the vulnerable period post harvest and replanting (~5-8 years long). Their findings found on harvested land, shallow landslides occur even in moderate storms on slopes >30°. They recommended a number of solutions including replanting within 12 months, retirement of steep areas such as gully heads that have higher erosion risk and stream/coastal setbacks.

33 Whilst I was not involved in drafting any of the PC1 notified provisions, when considering the potential effects on sediment load reductions from Policy WH.P28, P.P26, and Rules WH.R22 and P.R21 that prohibit the highest erosion risk land (plantation forestry) to be replanted after harvest, effectively retiring that land, I have the following comments:

33.1 Schedules 27 (Freshwater Action Plans for selected part FMU's) and schedule 34 (Plantation Forestry Erosion and Sediment Management Plan) encourage the highest erosion risk land to be replanted in appropriate native woody vegetation, including (where applicable) through 'planning, financial and logistical support for revegetation'.

33.2 Assuming a best case scenario that this land was actively replanted in natives within 1-2 years of harvest, this would contribute to reduced sediment loads, although the post-harvest 'risk window' described in paragraph 24 would likely increase to a minimum of 5 years, but potentially >10 years due to the time taken to establish canopy closure and stabilise soil on steep slopes with slower growing native species. Wills *et al.* (2024)[22] found canopy cover of manuka planted at 1000 stems/ha was expected after years 7-8 in ideal sites, and in less ideal sites subject to higher erosion or exposure, canopy closure could be greatly delayed even under higher planting densities.

33.3 Subsequently, replanting in native vegetation is likely to have a longer term benefit to sediment load reductions (i.e. >30 years post-harvest) when compared to replanting with *pinus radiata* (see Table 1 and Table 2) as only a single harvest cycle would occur, however, in the short term (i.e. by 2040), there may be greater reductions in sediment obtained by replanting rapidly in pine forest which grows faster and achieves canopy closure quicker than natives.

33.4 Under a worst case scenario, where the highest erosion risk land under plantation forestry was harvested and not replanted, instead left to naturally revert over time, this could increase the risk of sediment generation (compared to replanting in pines) in the short term (i.e. the next 10-20 years). It would be expected that in the long term (i.e. >30 years), this land would eventually have lower sediment yields than plantation forestry under continuing harvest cycles, however the net balance of sediment loads between these two landuses and the time to taken to achieve a reduction in sediment load from reverting land is difficult to quantify.

Hypothetical scenario of long term sediment loads from different landuses

34 While a number of studies discuss and compare the impacts of pasture and plantation forestry at different stages of land management, few document the relative (%) contributions of long-term sediment load that may occur from these different landuses. For this reason, I have developed a simple, hypothetical scenario of the potential sediment load from a catchment of unspecified size over a 30-year period in different landuses (native, pastoral or plantation forest including a harvest cycle of the entire catchment). An approximation of the pastoral sediment load (i.e. 1000 tonnes/year) was then used to predict the loads for the other landuses based off literature presented in this evidence.

34.1 The intent of these tables is to provide the Panels with guidance around the landuses relative (%) sediment loads when considering long term water quality TAS. The actual load is intended to be irrelevant in this respect. These tables are a generalisation and sediment generation may be different at the local scale depending on how the landuse is managed, the geology, slope and the climate that are present (noting that there are a lack of paired catchment studies in the Wellington Region, particularly within PC1). Connectivity of sediment to a stream is important (the SDR[1]), and strategic land management with appropriate setbacks could significantly reduce sediment load through interception methods.

35 **Table 1** summarises some of the assumptions applied to estimate average annual loads from different landuses, and **Table 2** presents an estimate of a 30-year 'long-term' total load, and proportions (%) compared to pastoral load over that period.

Table 1: Proportions of load relative to pasture were used to approximate sediment load from native and exotic forestry over a 30-year period (as presented in Table 2.

Landuse	Proportions assumed (relative to pasture load)	
Native	0.1x[2]	Equivalent to a 90% reduction, or pasture generating ~10x the load as native (paragraph 21, 22, and 23.1)
Mature Forestry (>5 years old)	0.1x	Equivalent to a 90% reduction, or pasture generating ~10x the load as plantation forestry (paragraph 21, 22, 23.1, 23.3)
Forestry Post Harvest (Year 0-3)	4x	Equivalent to four times the pastoral load post-harvest (see paragraphs 29.2, 30.2, 32.1, and 32.2)
Forestry Post Harvest (Year 4-5)	2x	Equivalent to 2x the load from pasture (an estimate at years 4–5) from paragraphs 29.2, 30.2, 32.1, and 32.2.

Table 2: Hypothetical scenario predicting relative (%) contributions of long-term average annual sediment loads in a catchment under different landuses, based off New Zealand literature. Proportions from Table 1 have been used to estimate loads off pasture. Complete clearfelling has been assumed for plantation forestry, to align with paired catchment studies in evidence.

<table>
<tr><th>Parameter</th><th>Pasture</th><th>Native</th><th>Mature Forestry (25 years)</th><th>Forestry Harvest (Year 0-3)</th><th>Forestry Harvest (year 4-5)</th></tr>
<tr><td>Annual Average Load (tonnes/year)</td><td>1,000</td><td>100</td><td>100</td><td>4,000</td><td>2,000</td></tr>
<tr><td>Years</td><td>30</td><td>30</td><td>25</td><td>3</td><td>2</td></tr>
<tr><td rowspan="2">Load (tonnes)</td><td rowspan="2">30,000</td><td rowspan="2">3,000</td><td>2,500</td><td>12,000</td><td>4,000</td></tr>
<tr><td colspan="3">18,500</td></tr>
<tr><td>Landuse</td><td>Total Load (30 years)</td><td>Proportion of total load (to pasture)</td><td colspan="3"></td></tr>
</table>

[2] As pasture is considered 1, this reflects 10% of the pasture load.

Parameter	Pasture	Native	Mature Forestry (25 years)	Forestry Harvest (Year 0-3)	Forestry Harvest (year 4-5)
Pasture	30,000	-			
Plantation Forestry	18,500	62%			
Native	3,000	10%			

36 **Table 2** provides an indication that assuming pastoral landuses delivers the greatest load over the long-term, plantation forestry may still deliver up to ~62% of the pastoral load, and up to 6 times that of a mature native catchment. This assumed the disturbed, post-harvest period lasts approximately 5 years. Not accounting for previous statements in paragraph 34.1, sediment load may change if:

36.1 Plantation forestry adopted best management practice, with replanting within 12 months, regular road maintenance and erosion control mitigations were in place (such as hydro seeding steep slopes). Pakuratahi study (paragraph 29) found load tripled over 2 years (harvest/post harvest), but by the end of year three loads had declined to ~25% of pasture sediment production (acknowledging the benefits of a lack of storms over this study period). Adopting these figures could result in a lower bound of 8,950 tonnes over 30 years (~30% of pastoral load) if applied in **Table 2**.

36.2 Large storms or above average rainfall occur during vulnerable periods. For plantation forestry, if this occurred during the harvest/post-harvest 'risk' period, this would increase the mobilisation of sediment and slash.

36.3 Adoption of a range of good land management practices (**LMP's**) on pasture (including but not limited to reducing stocking density, riparian planting, pole planting, retiring land, sediment traps and detainment bunds) would help decrease pastoral sediment loads. Some of these mitigations are covered in greater detail in evidence by Mr Peryer[23].

Summary of pasture versus plantation forestry sediment loads

37 To summarise some of the national papers presented in this evidence; when comparing catchments of similar climate, topography and geology, over the long-term native forest catchments will deliver the lowest sediment loads, likely followed by plantation forestry,

with pastoral landuses often delivering the highest sediment load. The majority of sediment from plantation forestry is delivered during and after harvest, with a risk 'window' typically <5 years, but up to 8 years when considering vulnerability to large storms. The sediment delivered from forestry during this window will highly likely be greater than pasture, however this load is dependent on the management practices (and maintenance), how soon the site is replanted, mitigations in place to reduce sediment connectivity to streams, and the likelihood of a large storm occurring.

38 When applying literature based values of sediment loads from different landuses to a hypothetical long-term (30 year) scenario of a catchment in pasture, native or plantation forestry (that would be subject to a clearfelling harvest cycle), I estimated that plantation forestry may deliver up to 62% of the equivalent pasture load, with a lower bound of ~30% of the load if best practice was implemented, rapid replanting and no significant storms occurred post-harvest. Noting there are a number of assumptions with this approach to be considered (see paragraphs 34.1 and 36.1 - 36.3).

VISUAL CLARITY MONITORING DATA WITHIN PC1

39 **Table 3** presents the dominant rural catchments in PC1 and their current state visual clarity from SOE monitoring data[24]. The total catchment area and relative (%) proportions of native, pastoral and plantation forestry has also been calculated from the New Zealand Land Cover Database V5.0[3] (LCDB V5.0)[25]. The purpose of this table is to provide an overview of visual clarity monitoring data (as a proxy measurement for fine suspended sediment) to compare against relative landuse within the monitored catchments.

40 Generally, **Table 3** shows catchments that have higher pastoral landuse proportions also have poorer visual clarity states, such as Horokiri Stream at Snodgrass, Pāuatahanui Stream at Elwood Bridge, Mangaroa River at Te Marua and Mākara Stream at Kennels. The catchments with predominantly plantation forest (i.e. Whakatikei River, Akatarawa River and Hulls Creek) are in an A attribute state (very good) for visual clarity, with the exception of Horokiri Stream at Snodgrass, which is in a C state (noting this catchment also has high proportions of pastoral landuse).

[3] The most current update to LCDB is 2018. Subsequently, comparisons to current state water quality monitoring data (2019-2024) are made assuming landuse change proportions are similar to 2018.

Table 3: Suspended Fine Sediment visual clarity current state derived from SOE monitoring data[24] for a selection of primarily rural catchments with the relative landuse proportions presented for native, pastoral and plantation forestry. Colour scales have been applied to help identify catchments with highest proportions of pastoral or plantation forestry.

SOE Monitoring Site	Total Area (ha)	Suspended Fine Sediment Current State	Native	Pastoral	Plantation Forest	Other
Horokiri Stream at Snodgrass	2,884	C	14%	41%	30%	16%
Whakatikei River at Riverstone	8,073	A	67%	6%	24%	2%
Hulls Creek Adjacent to Reynolds	1,517	A	31%	1%	22%	46%
Akatarawa River at Hutt Confluence	11,651	A	79%	3%	17%	1%
Mangaroa River at Te Marua	10,370	D**	49%	31%	16%	5%
Pāuatahanui Stream at Elwood Bridge	3,943	D**	21%	58%	15%	5%
Hutt River at Bolcoutt	61,021	B**	66%	11%	12%	11%
Porirua Stream at Milk Depot	4,026	A	13%	31%	11%	45%
Pakuratahi River Below Farm Creek	8,047	A	70%	11%	8%	11%
Mākara Stream at Kennels	7,203	D**	7%	64%	8%	21%
Wainuiomata River D/S of Whites Bridge	13,221	C**	65%	8%	3%	24%*

*18% of the catchment is exotic scrub (broom and gorse) that may still be grazed.

** Represent catchments that are required to reduce their suspended sediment load to meet visual clarity targets set by Whaitua Committees or because they fall below the NPS-FM national bottom line. See Blyth (2025)[2].

41 Larned *et al.* (2019)[26] provided a comprehensive review of the evidence of the effects of landuse on freshwater quality in New Zealand. They found in multiple studies:

41.1 Proportions of upstream catchment area with agricultural and urban land-cover were positively correlated with contaminant concentrations and loads in rivers and lakes, and negatively correlated with trophic, macroinvertebrate and fish-based eco-system health metrics. Landcover, however, was identified as being an imprecise proxy for the LMP's occurring within those landuses, with LMP playing a significant role on contaminant generation, connectivity to freshwater systems and corresponding downstream water quality.

41.2 In regards to plantation forestry, the authors found studies on the LMP of clear-fell harvesting to stream margins leads to increased deposited fine sediment, SS concentrations and loads, water temperature and light levels at stream surfaces, and decreased macroinvertebrate-based ecosystem-health metrics. The adverse effects indicated by macroinvertebrate metrics persisted for 1–8 years after harvesting, depending on catchment size and the presence of riparian buffers. In cases where riparian buffers were retained, adverse effects were consistently reduced.

42 I highlighted this paper in my evidence to emphasise the importance of best management practices (**BMP**), including mitigation devices, within varying landcovers (i.e. pastoral, urban or plantation forestry).

43 Drawing conclusions about the effects plantation forestry has on the aquatic environment based off SOE (monthly) monitoring data should be undertaken cautiously. I have not seen any compliance water quality monitoring or targeted plantation forestry harvest monitoring in the PC1 area to assess separately to SOE data. While some forested catchments are in an A attribute state (very good) for visual clarity, this may not reflect the sediment contributions of this landuse for a range of reasons, such as:

43.1 PC1 rural catchments are of predominantly mixed landuse (Table 3), and those with the highest area of forestry (Akatarawas and Whakatikei, totalling ~3,930 ha of plantation forestry) are part of large catchments with predominantly native forest landcover. This has significant benefits of dilution, and any harvest activities would likely be undertaken in localised blocks under rotation, rather than clearfelling of an entire catchment.

43.2 As an example, LCDB V5.0[25] provides an estimate of forestry harvest area. In 2018, there was 260 ha of harvested plantation forestry, and 1654 ha of maturing forest in Whakatikei River. This is a snapshot from the previous LCDB update in 2012 – with the area of harvested forest at different age classes <5 years old[25]. Harvested forestry over this period therefore represents only 3.2% of the catchment area.

43.3 Hulls Creek is a smaller catchment (1,517 ha) with 22% plantation forestry (**Table 3**). This would seem a likely catchment that would capture the effects of forestry harvest in relation to fine suspended sediment affecting visual clarity. However, LCDB V5.0[25] harvest data shows only 20 ha was harvested between 2012 and 2018 (with 273 ha remaining), representing only 1.3% of the catchment under harvest.

43.4 SOE monitoring is undertaken monthly, and usually at locations near the most downstream reach of a significant catchment. Subsequently, monitoring may not capture the localised impacts following harvest which are likely present at the tributary scale (i.e. REC order 2 or 3 streams) and instead SOE monitoring is a general representation of the overall catchment quality. Monthly monitoring may also miss some event-based sediment loads. Paragraph 32.2 highlights the significance of storm events in delivering the majority of sediment loads from harvested pine forests. Dr Greer discusses the variability in sediment delivery in respect to forestry activities and relevance to visual clarity at TAS sites in his HS2 rebuttal evidence, highlighting the importance of re-suspension and transport of this sediment within a stream/river channel[27].

43.5 The age profile of the trees will provide context about future harvested areas that may expand and potentially increase sediment load. Understanding of the age profile of plantation forests for the PC1 area has been covered in greater detail in Mr Reardons evidence[6].

44 To supplement the regional understanding of the potential sediment contributions from forestry activities, I have the following recommendations for the Council, each varying in regard to costs and efforts involved to obtain the data necessary to make more informed decisions. Longterm studies with continuous monitoring come at significant cost to the Council and subsequently, the rate payer, so are less likely to be adopted as a standard monitoring approach.

45 **Additional event-based monitoring at SOE sites**

45.1 Supplemental targeted spot samples and measurements could be undertaken during storm events at existing SOE sites. This would provide an increased paired sample count of total suspended solids (**TSS**) and visual clarity to help understand potential effects of landuse and LMP to inform the current clarity state.

45.2 Monitoring upstream of an SOE site could be undertaken, focussing on tributaries that may have greater proportions of plantation forestry under harvest or pastoral land, which could then be compared against SOE monitoring downstream, to better understand clarity and suspended sediment concentrations across the catchment.

45.3 A long-term study site (>5 years) could be established in a catchment, or tributary of a catchment, that is predominately plantation forestry subject to harvest in the short-term. This monitoring site should also have a flow station, continuous turbidity monitoring and autosampling of suspended sediment loads to develop a continuous flow and suspended sediment timeseries. Monitoring would ideally occur for a minimum of 2-3 years prior to harvest to establish a baseline, for comparison against the harvest period. A paired catchment study (against pastoral landuse) would be beneficial for the Wellington Region, however, would come at significant cost.

46 The Council may also choose to undertake additional compliance monitoring of forestry sites at their discretion and pass this cost onto forestry owners, as detailed in the National Environmental Standards for Commercial Forestry (MFE 2023[28]) Regulation 106 (amended). I am unaware if this has been occurring presently.

DATE: 15 APRIL 2025

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