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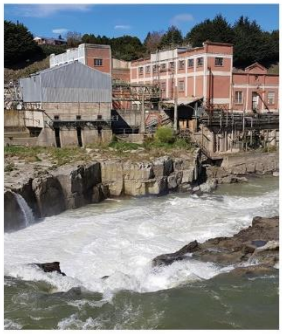

March 2023

Cyclone Gabrielle
Woody Debris Species Composition Assessment

Submitted to:

Hawke's Bay Regional Council

water fauna flora land

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Quality Assurance

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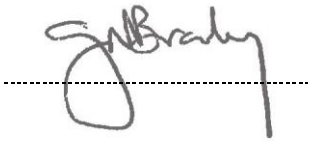

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1.0 Introduction

Plantation forestry is a significant land use in the Tairāwhiti Gisborne and Hawke's Bay regions, with each region having 157,295 ha and 139,598 ha under radiata pine respectively. The industry provides a number of soil conservation, water quality, employment, and economic benefits. There are, however, an increasing number of environmental, social and economic issues associated with this land use type. A key issue, and the one at focus in this report, is that of harvest and post-harvest large woody debris (LWD) mobilisation events after high intensity rainstorms and their impacts on our environment, communities, and infrastructure.

Post Cyclone Gabrielle, there is no longer any question that these types of LWD events represent a significant environmental and social issue for the communities within the East Coast and Hawke's Bay regions as well as an infrastructural and fiscal risk to physical assets (e.g., bridges) and their owners. LWD mobilisation events are of concern to the community because of the environmental and visual impacts and the increasingly common occurrence of property damage and the potential for loss of life. There are also significant post-event clean-up costs for asset owners and managers associated with mobilisation events.

Cyclone Gabrielle ravaged the Hawke's Bay between the 12th-14th of February 2023, just one month after Cyclone Hale had also affected the region. Hawke's Bay Regional Council (HBRC) rainfall figures revealed Cyclone Gabrielle to be one of the most significant to impact the region on record. The region's rain stations tell the story:

- In some places, including the Tukituki Valley, rainfall was even more intense than that experienced during Cyclone Bola in 1988.
- The Glengarry site recorded 546mm of rainfall, the most of all the region's sites, with almost 400mm falling in 12 hours at a maximum intensity of 56mm per hour.
- Totals along the southern coast reached 450mm during the storm – about a quarter of the usual annual rainfall there - with rainfall intensity peaking at nearly 40mm per hour.
- Being similarly exposed, the eastern area of Wairoa was the other part of the region, alongside Glengarry, to get more than 500mm of rain.
- Gabrielle delivered about 320mm of rain to the Newstead site, in the western hills of the Ahuriri catchment near Puketapu, which is about one-third of the usual annual rainfall there – most of it falling within 24 hours.
- Along with the rain came the wind. Gusts of up to 90kph were recorded, with exposed stations near the coast – such as Cape Kidnappers – seeing even higher wind gusts of up to 131kmh.

The result of this catastrophic weather bomb was that many waterways reached peak flood record levels, including the Mangaorapa, Porangahau and Taurekaitai streams and the Wairoa, Waipawa and Tukituki rivers. A major infrastructural risk was associated with LWD accumulating at road and rail bridges throughout the region. A total of 18 bridges suffered some degree of damage during Cyclone Gabrielle within the Hawke's Bay region alone.

HBRC engaged Ecological Solutions Limited to assess LWD at a number of locations across the Hawke's Bay region, including at a number of damaged infrastructure assets.

The aim of the assessment was primarily to determine the species composition, and if possible, gain insight as to the likely origins of LWD mobilised during Cyclone Gabrielle to help inform future land use planning objectives and outcomes.

2.0 Methodology

2.1.1 Assessment Sites

All assessment site coordinates were provided by Hawkes Bay Regional Council (HBRC). It is understood that site selection was based upon intelligence received from several sources including local residents and personnel engaged in the immediate emergency response. Sites therefore represented either known or likely sites of LWD accumulation at structures (e.g., road bridges) or on beaches.

Assessments were undertaken at 11 river sites and 6 beach sites by an ecologist from Ecological Solutions Ltd accompanied by a representative from HBRC between 28 February and 3 March 2023 (Figure 1).

2.2 Assessment categories

Large Woody Debris (LWD)[1] is defined as woody material more than 25cm in circumference (or 15cm diameter) irrespective of species and is a term used internationally to describe logs from various sources mobilised within a catchment (Cave, 2023). The Large Woody Debris Assessment Guide V.2.1 (Cave, 2023) was finalised and published during the assessment phase of this exercise. The broad methodologies described therein are the ones used to collect the data presented here. The full guide to the LWD assessment categories developed by Cave (2023), which include visual references for each category type, can be found in Appendix B.

The 11 categories for LWD assessment presented in Cave (2023) were not replicated exactly during this assessment. In particular five of Cave's categories relating to pine debris were grouped into one category called 'Cut Pine'. This was done for two primary reasons. First, assessments were required to be as rapid as possible in order to assess as many sites as possible per helicopter day. Second, a primary aim of this LWD assessment was to assess whether production forestry (and particularly harvesting activities), contributed to the woody debris accumulations observed throughout the region. An assessment grouping all pine LWD with evidence of harvesting activities (e.g., cut marks) would highlight this aspect in particular of the LWD assessed. We also created a new category for woody debris we called pine piece (not cut / not windthrow). We created this category because there did not appear to be an equivalent category in Cave (2023). For the purposes of this assessment the category *pine piece (not cut / not windthrow)* was defined as pine 'pieces' that do not have cut marks on either end, waratah marks, or rootballs attached. These pieces therefore could or could not be the result of production forestry activities (e.g., broken heads caused by tree felling, or broken heads caused by cyclonic winds).

A comparison of how the LWD assessment categories used in this assessment relate to the LWD assessment categories presented in Cave (2023) is provided in Table 1. The assessment categories used in this assessment are defined below.

[1] NB: the current assessment measured woody debris more than 15cm in diameter *and* more than 50cm in length.

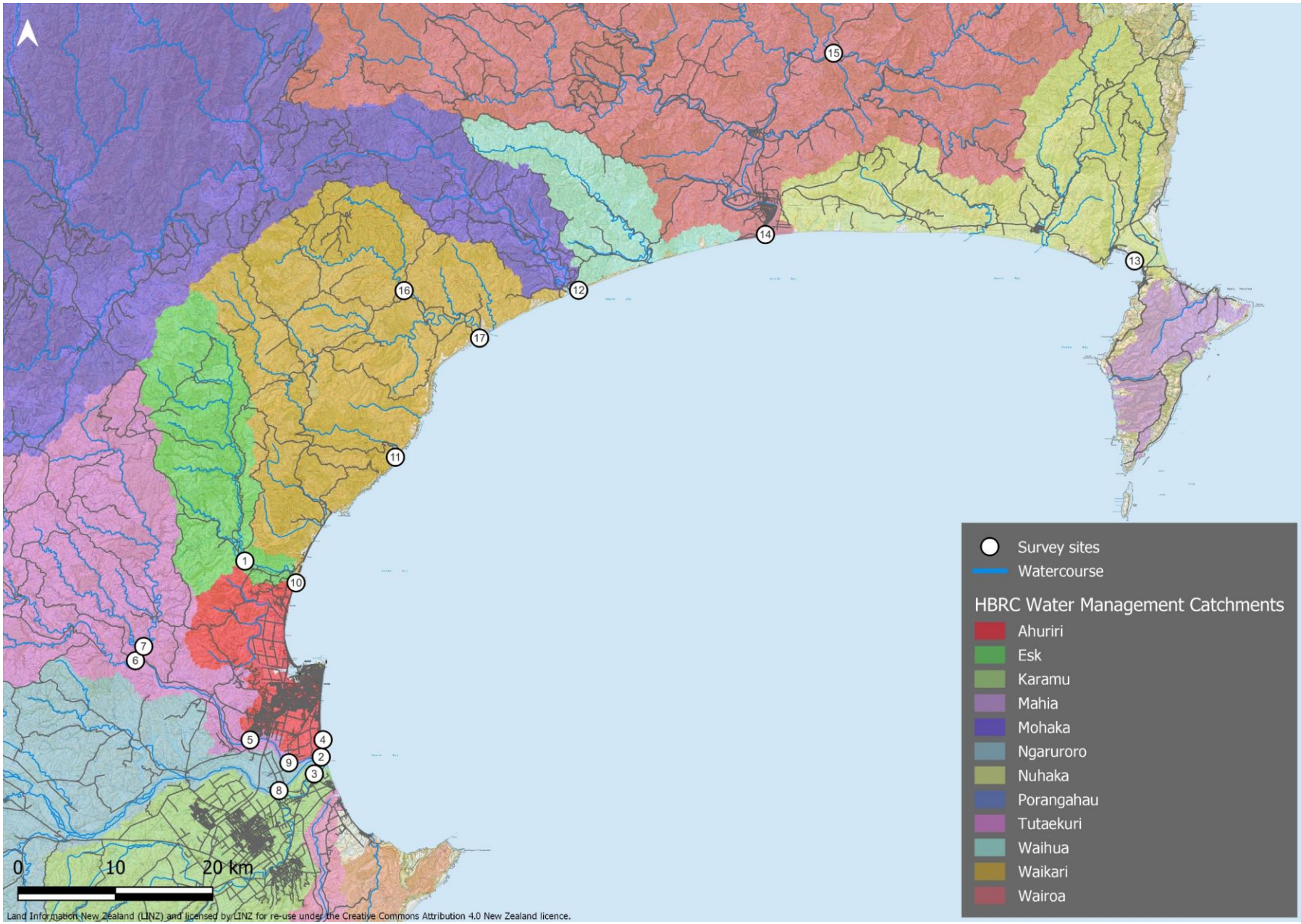

Figure 1: Large Woody Debris (LWD) assessment site locations.

Cut Pine

Any pine LWD with evidence of machinery marks was included in this category. The most prominent feature of debris in this category is a cut mark at one or both ends of the piece being assessed. Other marks could include indentations along a logs length from a processing head.

Long Resident Pine

Pine that has not been recently harvested. They may still have sharp ends but a weathering rind will be present or the ends will be uniformly weathered. In other instances, the cut ends will have been rounded off and can form cone shapes. Waratah marks may still be present. The trunk may look relatively fresh or may be grey.

Table 1: Comparison of current assessment categories with Cave (2023).

ESL (2023) category	Cave (2023) category
Cut Pine	Fresh cut pine
	Slovens
	Short cut pine rootballs
	Long cut pine rootballs
	Cut to waste pine
Long resident pine	Long resident logs
Fresh cut pine	Post-event modified logs
Pine Piece (not cut / not windthrow)	
Windthrow pine	Rootball pine with full or partial trunks
Willow/poplar	Willow, Poplar and Acacia
Windthrow willow/poplar	Willow, Poplar and Acacia
Other	Indigenous
	Slash
Excluded from assessment	Dross
	Fence posts and battens and rubbish

Fresh Cut Pine

This may include material on a beach which is the burnt remnant of prior clean-up operations and/or long resident logs where the community has cut and removed rounds for firewood.

Pine Piece

LWD of pine origin not evidencing cut (or other) marks indicating that they had been harvested. A typical piece in this assessment category would consist of a length of pine woody debris broken at each end). While there is no marks evidencing pieces result from

harvest activity, assignment to this category also cannot preclude it.

Windthrow Pine

Often referred to as windthrow but the provenance of such material is not confined to the action of wind-induced downbursts and can be derived from riparian erosion, landsliding, or dislodgement during the harvesting of adjacent trees. May have partial or significant loss of bark.

Willow / Poplar

Willows (*Salix* spp.) and Poplar (*Populus* spp.) are the most common erosion and riparian margin control species used within the region. They can generally be readily distinguished from pine by their different bark textures and markings, although willow and poplar bark can be quite variable in texture. Poplar can have a slim relatively straight truck and normally finer bark. Debarked poplar will often have a dimpled texture and a spiral crack system. Willow generally has an irregular trunk and if it's a whole tree will show a long root system. This category only included specimens without rootballs attached.

Windthrow Willow / Poplar

As above, but with rootballs attached.

Other

Many different species of indigenous vegetation can be incorporated within the woody debris and these can include softwoods, semi-hardwoods, and mānuka/kānuka (*Leptospermum scoparium* agg., *Kunzea* spp.). These are generally readily distinguished from either pine or the willow/poplar suite. This category also included any LWD that could not be assigned to any other category with certainty.

2.3 Assessment Types

In an ideal world every piece of LWD would be counted, but the very large volumes involved means that this is impractical in most instances. Instead, subsets of the woody debris field are counted. Provided that sufficient replicate assessments are undertaken, the data can be considered representative. At most sites, especially those at the coast, the debris field extended for kilometres along the shoreline.

Cave (2023) proposes three primary methodologies for on-the-ground rapid assessments:

- 10 metre square plots
- Transects
- Wood pile counts

Both the 10m square plot and wood pile count methodologies were utilised during this assessment, along with a visual estimation of percentage volume. Each of these methodologies is described in more detail below.

2.3.1 10m square plots

Three equally spaced plots (approximately 50m apart) where a 10m square area was dominated by LWD were established. Every piece of LWD over 15cm in diameter and 50cm in length within each plot was counted and then were dazzle-painted to ensure that they were only counted once. Plots were photographed from each corner with a GPS enabled (phone) camera for later exporting to a Geographic Information System (GIS).

A visual estimate of the percentage area of the plot covered by slash or dross was not

made. However, in almost every plot, the average area covered by woody debris exceeded 95% (9.5m^2).

For LWD that extended beyond the plot area, Cave (2023) proposes that any log where 25% or less of the log sits outside the plot is counted while logs which are only 25% within the plot area are excluded. This rule was modified slightly for the current assessment in order to accommodate the large number of full-length stems (i.e., whole trees) observed, often with rootballs still attached, and typically measuring 30-40m in length. Such logs would almost always be excluded from assessment by Cave's 25% limits unless they lay through the plot. The current assessment instead excluded full stems / logs over 20m in length only if they did not have more than 2.5m of their length within the plot. This modification may therefore lead to an over representation of this type of LWD when compared to plots assessed using Cave's 25% rule.

2.3.2 Wood pile counts

Wood piles may occur naturally when LWD gets lodged against standing trees on the flood plain or be the result of urgent works undertaken to clear log jams against bridges that could otherwise fail. Cave (2023) proposes two options for counting wood piles:

A digger can be used to pull apart the piles and place them in separate sub-piles based on species class for counting. Unfortunately, due to the nature of emergency works being undertaken by the machinery at some sites in this study (e.g., rebuilding stopbanks or removing debris from bridges), attempts to organise assessments using the '*wood pile – deconstruction*' method were unsuccessful.

As the use of a digger was not possible, hand counting in-situ was necessary. Because it was often not possible to count all logs in a pile since they may be obscured, or it was too hazardous to get close enough to count, the upstream face of piles was assessed. This essentially replicated a 10m square plot but in the vertical rather than horizontal plane (noting that pile assessment dimensions were not standardised). For safety reasons clambering over (or under) wood piles was avoided. Wood piles were assessed with the aim of counting three piles and a minimum of 100 pieces of LWD at each site.

2.3.3 Visual estimation of percentage volume

A visual estimation of the percentage volume of pine in terms of total LWD volume was made. This additional data point was collected to offset the potential risk that a few large pieces of LWD may be overrepresented in volume but underrepresented in piece counts within the same plot or pile.

For example, a large windthrow willow/poplar may comprise 90% of wood volume within a pile with 49 small pieces of pine that comprise just 10% of wood volume. By volume then, willow/poplar is clearly the predominant LWD type, but the *wood pile – hand count* or *10m square plot* methodologies described above would present data suggesting that willow/poplar contributed just 2% of LWD while pine contributed 98%.

3.0 Woody Debris Assessments

3.1 Site 1: Esk River at Waipunga Road Bridge

This site was visited on 28 February 2023. There had been some emergency work done with machinery to both clear the debris accumulation from the bridge and reconstruct the bridge approach. While assessment could have been conducted on any of the piles created by machinery, it was decided to assess natural (i.e., undisturbed) debris accumulations. This was achieved in three locations (upstream and downstream and on the true left and right banks) where debris had accumulated on the upstream side of riverside trees where the '*wood piles – hand counting*' methodology was used to assess woody debris species composition. In total, 111 pieces of LWD were categorised.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed were 75%, 18% and 7% respectively (Figure 42).

By volume, pine was visually estimated to comprise 75% of the woody debris present within the piles assessed, with willow/poplar and other species comprising the remainder.

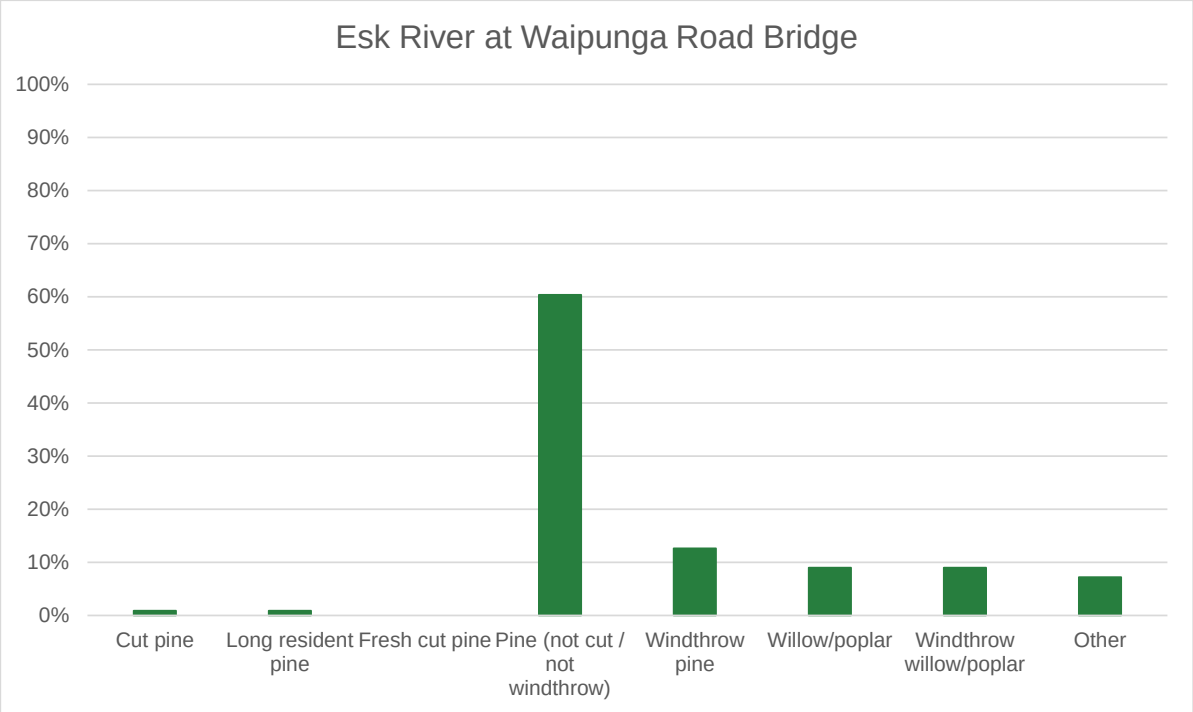

Figure 2: Within species breakdown of woody debris by piece type at Site 1.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 1% Figure 2). The proportion of long resident pine debris was similarly low (1%). Interestingly the proportion of both windthrow pine (13%) and windthrow willow/poplar (9%) were similar.

The overwhelming majority of woody debris was however pine 'pieces' (60%) which constituted pieces of woody debris not evidencing cut (or other) marks indicating that they had been harvested.

Figure 3: View upstream from the true right bank at Site 1.

Figure 4: Typical woody debris accumulation assessed at Site 1.

3.2 Site 2: Tutaekuri / Ngaruroro River at State Highway 51 Bridge

This site was visited on 1 March 2023. Three different piles of LWD accumulation were assessed. In total, 123 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed were 38%, 37% and 24% respectively (Figure 42).

By volume, pine was estimated visually to comprise 18% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

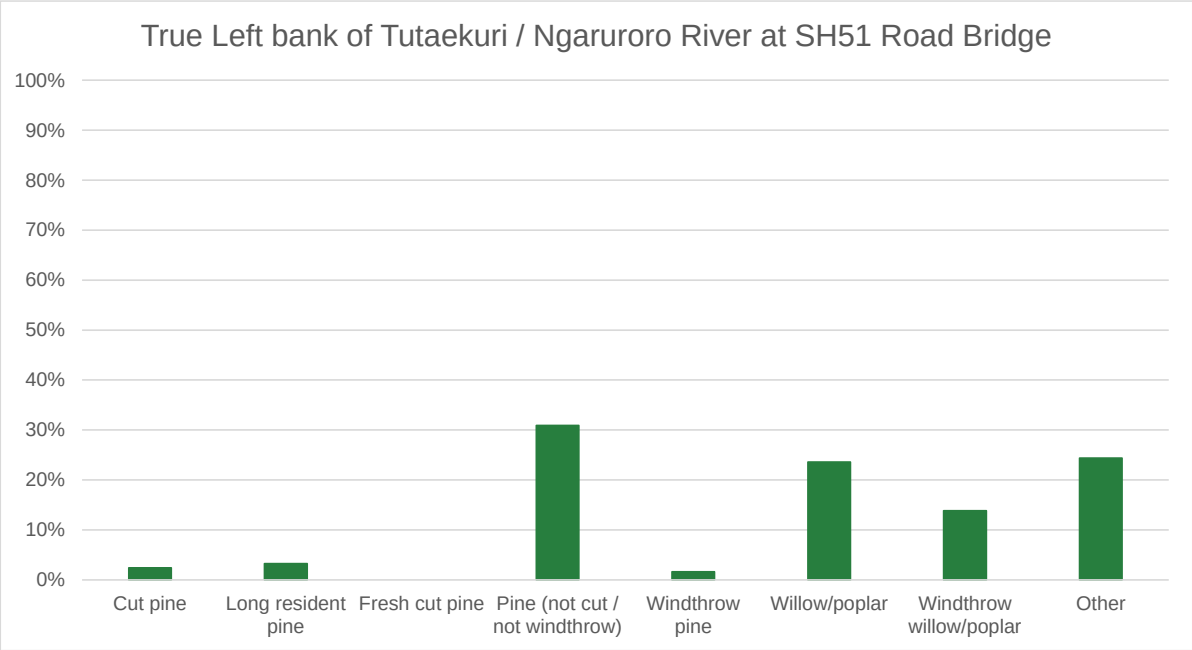

Figure 5: Within species breakdown of woody debris by piece type at Site 2.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 2% (Figure 5). The proportion of long resident pine debris was similarly low (3%). Interestingly the proportion of both windthrow pine (2%) and windthrow willow/poplar (14%) were quite different, perhaps reflecting the scale of river protection plantings within the catchment[2].

The majority of woody debris was however pine 'pieces' (31%) which constitute pieces of woody debris not evidencing cut (or other) marks indicating that they had been harvested.

[2] The Tutaekuri and Ngaruroro Rivers have 247,126 m and 294,103 m of willow and poplar river protection plantings respectively.

Figure 6: View downstream from the true left bank at Site 2.

Figure 7: Typical woody debris accumulation assessed at Site 2.

3.3 Site 3: Tutaekuri / Ngaruroro River at Railway Bridge

This site was visited on 1 March 2023. Three different piles of LWD accumulation were assessed. In total, 120 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed was 38%, 46% and 21% respectively (Figure 42). These percentages were similar to Site 2 immediately downstream at the State Highway 51 road bridge with the percentage of pine and other species decreasing slightly (5% and 3% respectively) and the percentage of willow/poplar increasing slightly (9%).

By volume, pine was visually estimated to comprise 24% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

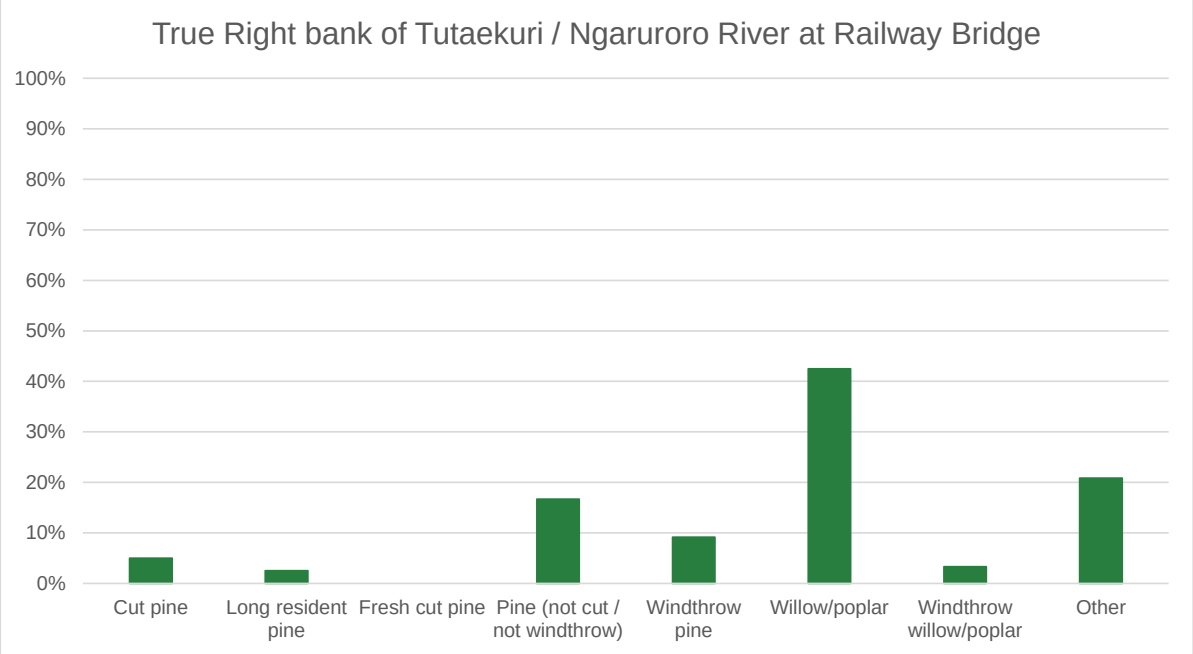

Figure 8: Within species breakdown of woody debris by piece type at Site 3.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 5% (Figure 8). The proportion of long resident pine debris was 3%.

The proportion of windthrow pine (9%) and windthrow willow/poplar (3%) were again different, there was apparently less variation than at Site 2 immediately downstream where less windthrow pine (2%) and more windthrow willow/poplar (14%) was evident. However, total windthrow accounted for similar proportions of LWD at Site 3 (12%) and Site 2 (16%).

The majority of woody debris assessed was willow/poplar (43% - not including the 3% categorised as windthrow), with the next highest categories being other species (21%) and pine 'pieces' (17%).

Interestingly, and uniquely, this site (or approximately 200 m upstream of it) was the only location assessed which evidenced an accumulation of cut (and stencilled) pine logs. These 40 – 60 large logs, which were a mix of pine and other merchantable species, had seemingly been deposited along the true right bank of the waterway as the flood flows receded.

Figure 9: View downstream from the true right bank at Site 3.

Figure 10: Typical woody debris accumulation assessed at Site 3.

3.4 Site 4: Tutaekuri / Ngaruroro River mouth

This site was visited on 1 March 2023. Three different piles (10m x 10m plots) of LWD accumulation were assessed. In total, 235 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed were 29%, 37% and 34% respectively (Figure 42). These percentages were similar to Site 2 and Site 3 immediately upstream with the percentage of pine decreasing only slightly (4-9%), the percentage of willow/poplar remaining constant or increasing slightly (0-9%), and the percentage of other species increasing slightly (10-13%). The increase in the percentage of other species in the coastal environment could reflect the increase in (usually small) unidentifiable woody debris present (e.g., due to time in water / abrasion removing distinctive features necessary for a positive species identification).

By volume, pine was estimated visually to comprise 18% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

The species composition average for Sites 2-4 which each reflect the Tutaekuri / Ngaruroro River are pine (M = 33%, SD = 5%), willow/poplar (M = 40%, SD = 5%) and other species (M = 27%, SD = 7%).

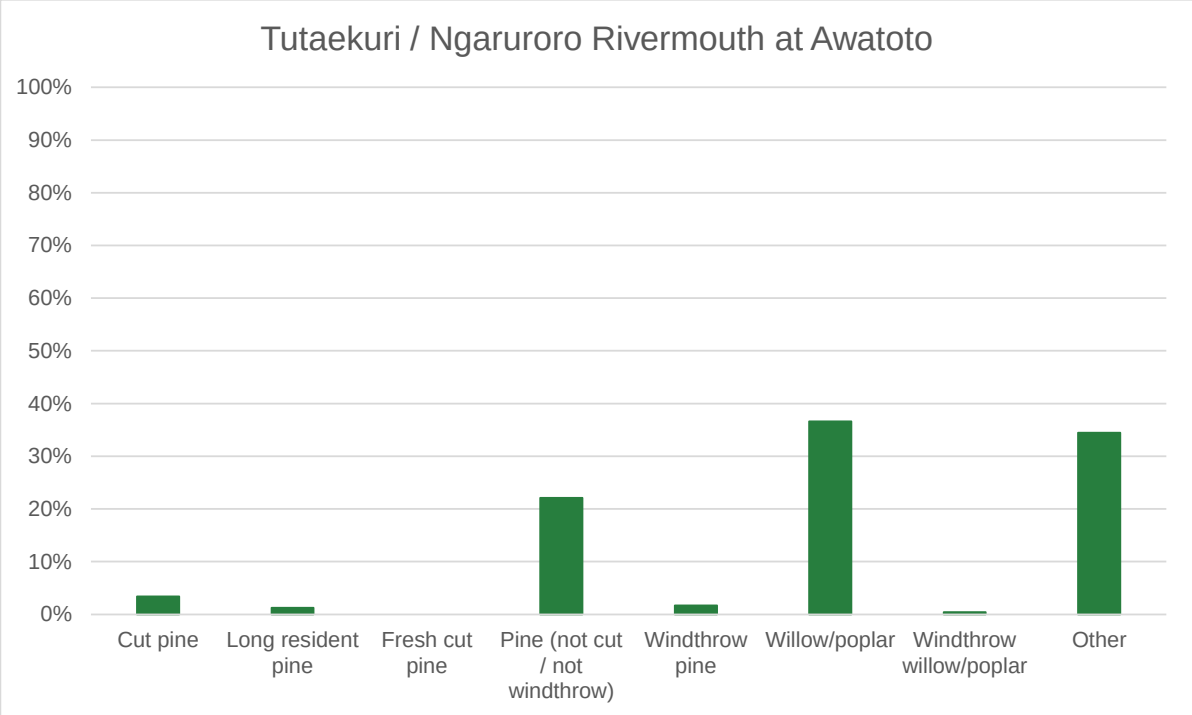

Figure 11: Within species breakdown of woody debris by piece type at Site 4.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 3% (Figure 11). The proportion of long resident pine debris was similarly low (1%). The low proportions of both windthrow pine (2%) and windthrow willow/poplar (<1%) may reflect the fact that much of this material was held up at the road and rail bridges (Site 2 and Site 3) where windthrow proportions were higher at 16% and 12% respectively.

The majority of woody debris assessed was willow/poplar (37% - not including the <1% categorised as windthrow), with the next highest categories being other species (34%) followed by pine 'pieces' (22%).

Figure 12: View south over the river mouth at Site 4 showing plot with dazzled wood.

Figure 13: Typical woody debris accumulation assessed at Site 4.

3.5 Site 5: Tutaekuri River at Redclyffe Bridge

This site was visited on 1 March 2023. Due to accessibility issues, this site was not able to be safely assessed using any of the methods outlined by Cave (2023). It had been intended to utilise the '*wood pile – deconstruction*' methodology to count LWD accumulations at this location. Due to the urgent nature of the work being undertaken to clear debris from the bridge and rebuild the stopbank, woody debris was not available to assess at the designated disposal site (Figure 14). It was therefore decided to undertake a basic visual assessment only. NB: the visual assessment was undertaken from the same location as the photo in Figure 14 where the upstream face of the debris accumulation was best viewed. It may be possible (and if so is recommended) to undertake a more formal assessment of the LWD disposal pile at a later date.

A visual estimation of the percentage volume of pine, willow/poplar and other species in the woody debris accumulation at the bridge was 5%, 90% and 5% respectively (Figure 42).

Comparing this assessment with the results from Site 2 and Site 3 (but excluding Site 4 on the grounds of it being a beach site) it is evident that the proportion of pine is below the average of those sites (M = 36, SD = 3%), as is the proportion of other species (M = 23%, SD = 3%), while willow/poplar was assessed as being significantly higher (M = 42%, SD = 6%). These differences may be a true reflection of the LWD composition at this site, or (perhaps more likely) an artefact of the visual assessment methodology used (which is somewhat of a mix of a '*wood pile - hand count*' and '*percentage volume*' estimate.

Figure 14: View from the true left bank over the destroyed Redclyffe Bridge at Site 5.

3.6 Site 6: Mangaone River at Dartmoor Road Bridge

This site was visited on 2 March 2023. Three different piles of LWD accumulation were assessed. In total, 88 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed were 57%, 32% and 11% respectively (Figure 42).

By volume, pine was estimated visually to comprise 55% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

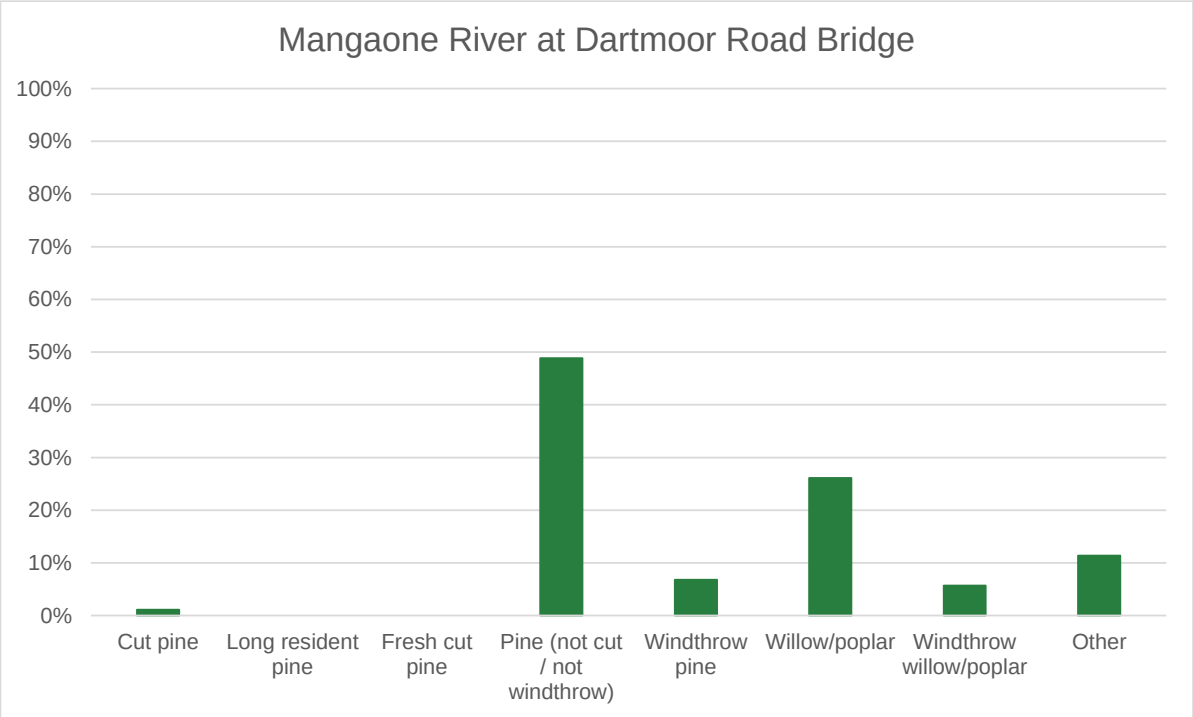

Figure 15: Within species breakdown of woody debris by piece type at Site 6.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 1% (Figure 15). The proportion of long resident pine debris was similarly low (0%). Interestingly the proportion of both windthrow pine (7%) and windthrow willow/poplar (6%) were similar and approximated the average of all sites assessed (M = 6% for windthrow pine, and M = 3% for windthrow willow/poplar).

The overwhelming majority of woody debris was however pine 'pieces' (49%) which constitute pieces of woody debris not evidencing cut (or other) marks indicating conclusively that they had been harvested (although that source of origin also cannot be completely ruled out). Willow/poplar was the next most frequently observed LWD contributing approximately half the number of pieces as pine 'pieces' (26%).

Figure 16: View downstream along the true right bank and over Site 6.

Figure 17: Typical woody debris accumulation assessed at Site 6.

3.7 Site 7: Tutaekuri River upstream of confluence with Mangaone Stream

This site was visited on 2 March 2023. Three different piles of LWD accumulation were assessed. In total, 149 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed were 60%, 27% and 13% respectively (Figure 42).

By volume, pine was estimated visually to comprise 53% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

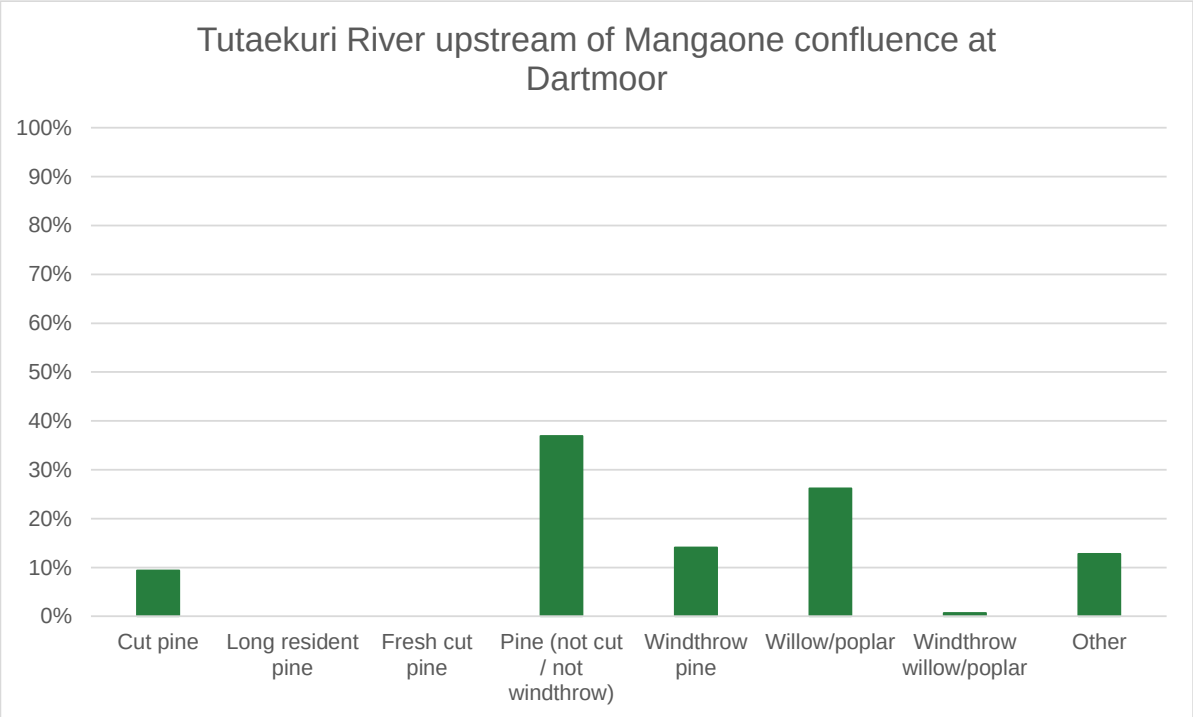

Figure 18: Within species breakdown of woody debris by piece type at Site 7.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 9% - the highest proportion recorded at any site assessed (Figure 18). This represents 8% more cut pine pieces than was observed at Site 6 (very close nearby but in a different river system) where only 1% of LWD was categorised as cut pine. The proportion of long resident pine was low (0%), suggesting that the cut pine LWD present had entered the river system recently (potentially and perhaps most likely during cyclone Gabrielle).

Interestingly the proportion of both windthrow pine (14%) and windthrow willow/poplar (1%) were quite different from not only each other, but also the values recorded at Site 6 (very nearby but in a different river system) where values were 7% and 6% for windthrow pine and windthrow willow/poplar respectively.

The majority of woody debris was however pine 'pieces' (37%) which constitute pieces of woody debris not evidencing cut (or other) marks indicating that they had been harvested. This value also represents the average value for pine 'pieces' across all sites assessed by either the *wood pile – hand count* or *square plot* method (N = 11, M = 37%, SD = 14%). Willow/poplar was the next most frequently observed LWD contributing 26% of LWD pieces.

Figure 19: View downstream along the true left (stop)bank and over Site 7.

Figure 20: Typical woody debris accumulation assessed at Site 7.

3.8 Site 8: Ngaruroro River at Chesterhope Bridge

This site was visited on 2 March 2023. Since the bridge was almost completely free of debris no assessment was undertaken. This fact is however both a useful and interesting data point as the Tutaekuri and Ngaruroro River have their confluence near Site 2, Site 3 and Site 4 where a significant amount of LWD accumulated, resulting in damage to two bridges. This perhaps provides an opportunity to investigate upstream land use differences.

Figure 21: View downstream from the true left bank and over Site 8.

Figure 22: A windthrown willow was one of the few pieces of LWD seen at Site 8.

3.9 Site 9: Tutaekuri River at Brookfields Bridge

This site was visited on 2 March 2023. Only one pile of LWD accumulation was present. As such, the entire pile was assessed. In total, 65 pieces of LWD were categorised.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed was 32%, 58% and 9% respectively (Figure 42).

By volume, pine was estimated visually to comprise 20% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

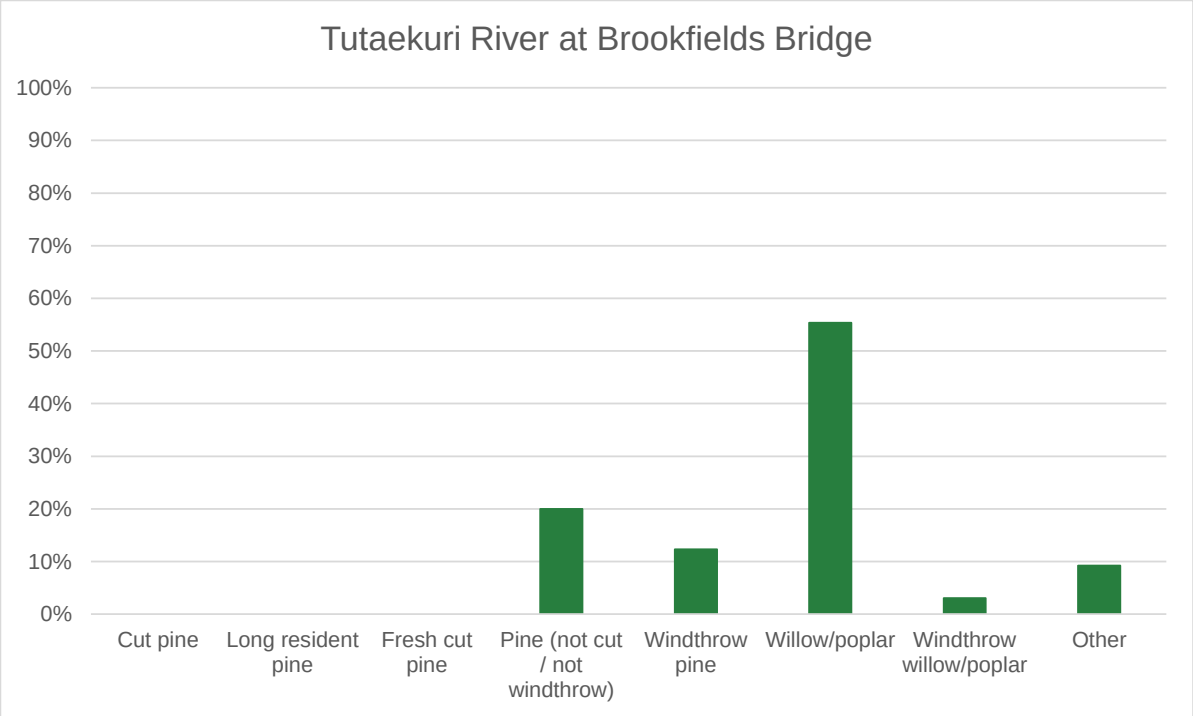

Figure 23: Within species breakdown of woody debris by piece type at Site 9.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 0% (Figure 23). The proportion of long resident pine debris was similarly low (0%). The proportion of windthrow pine (12%) was higher than the average of all sites assessed calculated in Section 3.18 (N = 11, M = 6%, SD = 5%) while windthrow willow/poplar (3%) was average (N = 11, M = 3%, SD = 5%).

The overwhelming majority of woody debris was willow/poplar (55%) with pine 'pieces' being the next most frequently observed LWD but contributing approximately one third the number of pieces (20%) as willow/poplar.

Figure 24: View upstream from the true right bank and over Site 9.

Figure 25: A single woody debris accumulation was available to assess at Site 9.

3.10 Site 10: Esk River mouth

This site was visited on 2 March 2023. Three different piles of LWD accumulation were assessed. In total, 357 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed was 63%, 6% and 31% respectively (Figure 42). These proportions were 12% lower for both pine and willow/poplar but 24% higher for LWD categorised as other species compared with Site 1 farther upstream at the Waipunga Road Bridge (Figure 42). As for Site 4 at Awatoto Beach, the increase in the percentage of other species in the coastal environment could reflect the increase in (usually small) unidentifiable woody debris present (e.g., due to time in water / abrasion removing distinctive features necessary for a positive species identification).

By volume, pine was estimated visually to comprise 87% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder. This is in keeping with the estimated contribution of pine by volume to the LWD accumulations assessed at Site 1 upstream (75%).

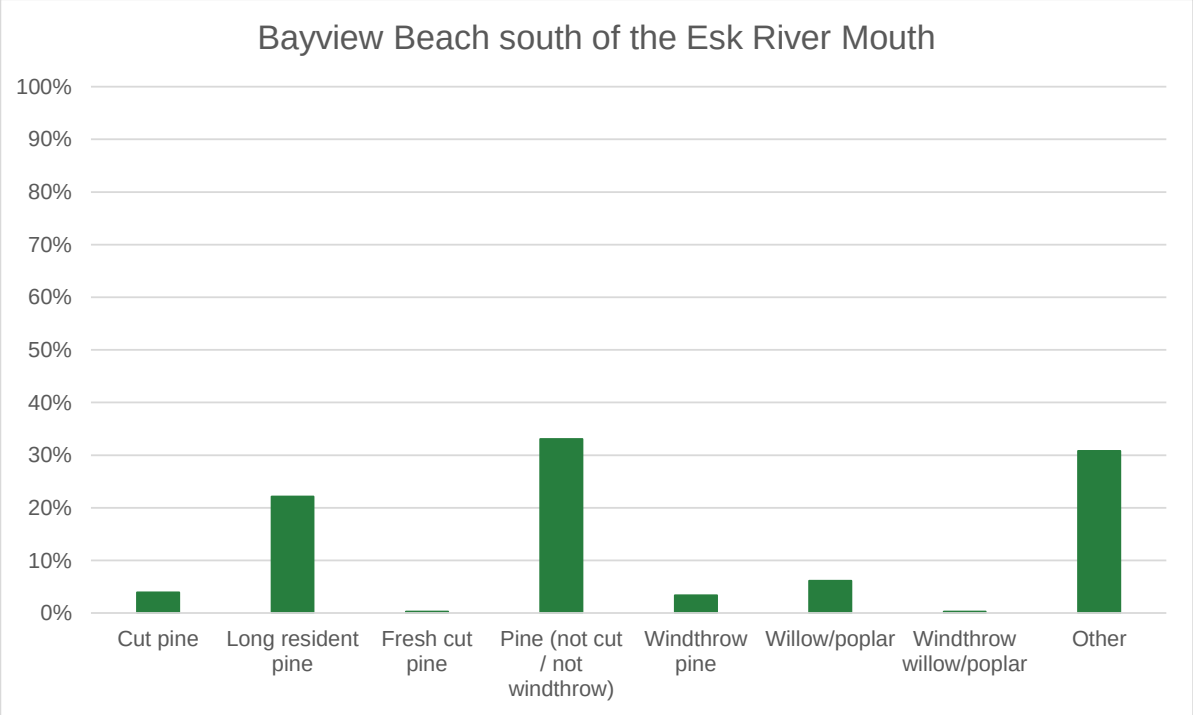

Figure 26: Within species breakdown of woody debris by piece type at Site 10.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 4% (Figure 26). The proportion of long resident pine debris was the highest of any site assessed at 22% (N = 11, M = 7%, SD = 9%). Interestingly the proportion of both windthrow pine (3%) and windthrow willow/poplar (0%) were both relatively low at this location.

The majority of woody debris was pine 'pieces' (33%), but in this instance not too dissimilar from either other species (31%) or long resident pine (22%). The presence of a large proportion of long resident pine may suggest that LWD within the Esk River catchment is not solely the result of Cyclone Gabrielle. However, long resident pine did not feature as prominently at Site 1 upstream where just 1% of LWD was assigned to this category.

Figure 27: View north along the coast towards the Esk River mouth (Site 10 to south).

Figure 28: Typical woody debris accumulation assessed at Site 10 (view south).

3.11 Site 11: Aropaoanui River mouth

This site was visited on 3 March 2023 via helicopter. In the interests of time just two plots of LWD accumulation were assessed. In total, 347 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed was 77%, 11% and 12% respectively (Figure 42).

By volume, pine was estimated visually to comprise 93% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

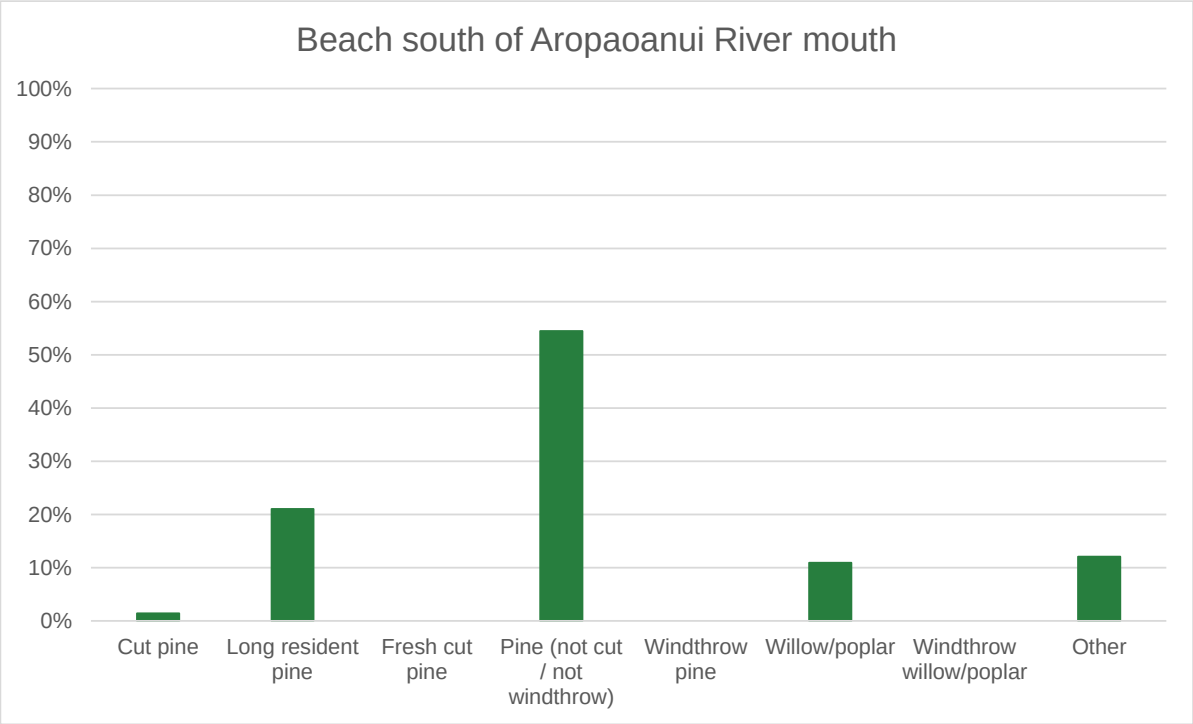

Figure 29: Within species breakdown of woody debris by piece type at Site 11.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 1% (Figure 29). The proportion of long resident pine debris was the second highest of any site (21%). The proportion of long resident pine LWD was lower than Site 10 to the south (22%) but higher than Site 12 to the north (15%). Interestingly the proportion of both windthrow pine (0%) and windthrow willow/poplar (0%) were the lowest of any site assessed. These proportions were similar only to Site 13 at Mahia Beach to the north where no windthrow material was recorded either.

The overwhelming majority of woody debris was however pine 'pieces' (33%) and long resident pine (21%). Many pieces categorised as long resident pine would have been categorised as pine 'pieces' if they had been of more recent origin (i.e., they too did not have any evidence of cut / processing marks associated with harvesting activity). Willow/poplar and other species were the next most frequently observed LWD categories contributing approximately only one third the number of LWD pieces counted as pine 'pieces' (11% and 12% respectively) and just half as much as long resident pine pieces counted.

Figure 30: View north over the Aropaoanui River mouth and Site 11.

Figure 31: Typical woody debris accumulation assessed at Site 11.

3.12 Site 12: Mohaka River mouth

This site was visited on 3 March 2023 by helicopter. Three different plots of LWD accumulation were assessed. In total, 172 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed were 63%, 8% and 29% respectively (Figure 42).

By volume, pine was estimated visually to comprise 78% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

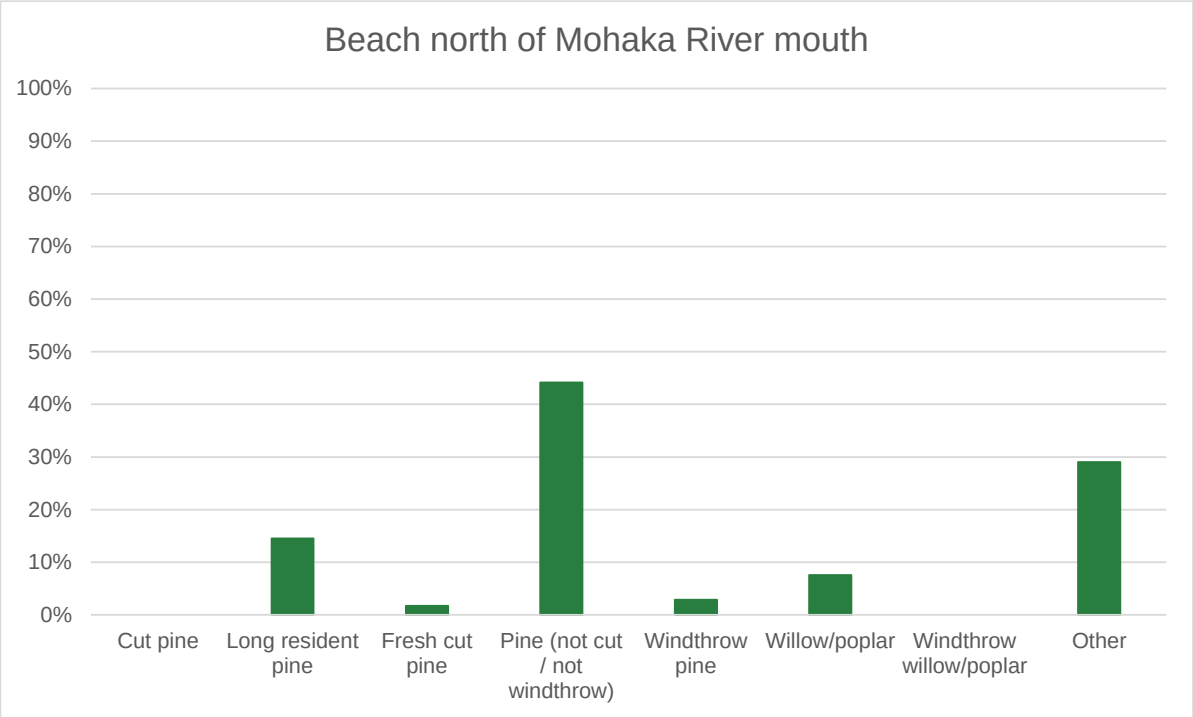

Figure 32: Within species breakdown of woody debris by piece type at Site 12.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 0% (Figure 32). The proportion of long resident pine debris was the third highest of any site (15%). The proportion of long resident pine LWD was lower than Sites 10 and 11 to the south (22% and 21% respectively). The proportions of both windthrow pine (3%) and windthrow willow/poplar (0%) were low. The low proportion of windthrow willow/poplar was evidenced by all five beach assessment sites (where in fact no windthrow willow/poplar was recorded). That is not to say this LWD did not exist at beach sites, as pieces fitting that assessment category were observed outside assessment plots.

The overwhelming majority of woody debris was pine 'pieces' (44%) which constitute pieces of woody debris not evidencing cut (or other) marks indicating that they had been harvested. Other species was the next most frequently observed LWD (26%) followed by long resident pine (15%).

Figure 33: View north over the Mohaka River mouth and Site 12 on the northern bank.

Figure 34: Typical woody debris accumulation assessed at Site 12.

3.13 Site 13: Mahia Beach

This site was visited on 3 March 2023 via helicopter. Three different plots of LWD accumulation were assessed. In total, 436 pieces of LWD were categorised. The data was averaged across these replicates and is presented and discussed below.

The proportion of pine, willow/poplar and other species in the woody debris accumulations assessed was 44%, 8% and 48% respectively (Figure 42).

By volume, pine was estimated visually to comprise 43% of the woody debris present within the accumulations assessed, with willow/poplar and other species comprising the remainder.

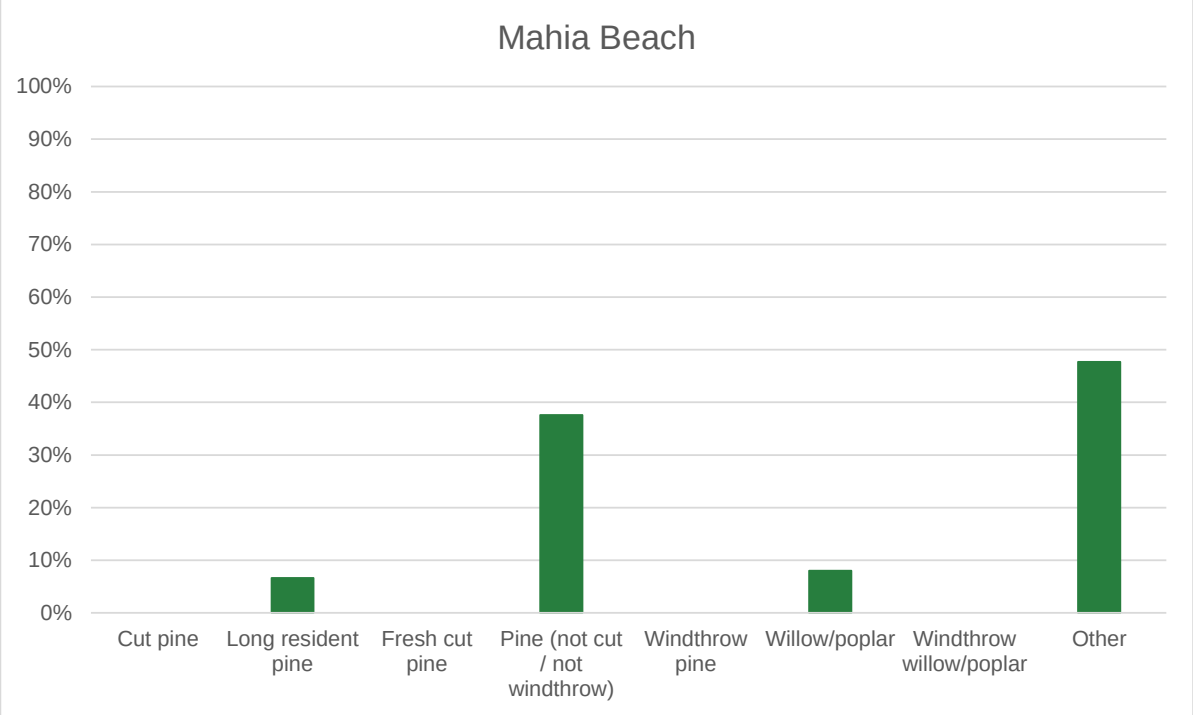

Figure 35: Within species breakdown of woody debris by piece type at Site 13.

The proportion of cut pine (whose source would be historic or current forestry harvesting operations) was 0% (Figure 35). The proportion of long resident pine LWD was (7%). The proportion of both windthrow pine was low (0%) and like all other beach sites windthrow willow/poplar was not present with survey plots (0%).

The majority of woody debris was split fairly evenly between other species (48%) and pine 'pieces' (38%) which constitute pieces of woody debris not evidencing cut (or other) marks indicating that they had been harvested. Willow/poplar contributed only 8% of LWD assessed. The high percentage of other species in the coastal environment at this site in part reflects the increase in (usually small) unidentifiable woody debris present (e.g., due to time in water / abrasion removing distinctive features necessary for a positive species identification) that most people would recognise as '*driftwood*'.

Figure 36: View north over Mahia Beach and Site 13.

Figure 37: Typical woody debris accumulation assessed at Site 13.

3.14 Site 14: Wairoa River mouth

This site was visited on 3 March 2023 by helicopter. Much of the coastline evidenced the recent arrival of significant amounts of woody debris likely originating from the Wairoa River. A particularly dense and expansive accumulation of LWD was apparent on the southern (true right) bank of the Wairoa River close to the river mouth. It appeared that perhaps this debris had been corralled by the tide as it moved downstream and was forced ashore where it remains.

Unfortunately, no suitable and safe landing location was available, so this site was not able to be assessed using quantitative methods. The site was therefore assessed using the qualitative *visual estimation of percentage volume* methodology. It is recommended that this site is revisited and assessed quantitatively once access is safely obtainable.

The proportion of pine, willow/poplar and other species in the woody debris accumulation at the bridge was visually assessed as comprising 90%, 5% and 5% respectively (Figure 42).

Figure 38: View south over the true right bank of the Wairoa River and Site 14.

3.15 Site 15: Mangapoike River at Tiniroto Road Bridge

This site was visited on 3 March 2023 by helicopter. Unfortunately, no suitable and safe LWD accumulations were identified that were able to be assessed using quantitative methods. The site was therefore assessed using the qualitative *visual estimation of percentage volume* methodology.

The proportion of pine, willow/poplar and other species in the woody debris accumulation at the bridge was visually assessed as comprising 90%, 5% and 5% respectively (Figure 42).

Based on qualitative observations only, the predominant LWD category represented here by count and volume was pine 'pieces' (estimated >80%). While some evidence of LWD that would be classified as cut pine was observed, this did not comprise a significant proportion by count or volume (estimated <10%).

It is recommended however that this site is revisited and assessed quantitatively once access is safely obtainable. This may be best achieved using the *wood pile – deconstruction* methodology, assuming that the woody debris is able to be safely removed and stockpiled elsewhere. In addition, given the volume and type of material present, further investigation as to potential material sources within the Mangapoike River catchment is recommended.

Figure 39: View over the Mangapoike and Wairoa River confluence and Site 15.

3.16 Site 16: Waikare River at State Highway 2 Bridge

This site was visited on 3 March 2023 by helicopter. Unfortunately, no suitable and safe landing location was available, so this site was not able to be assessed using quantitative methods. The site was therefore assessed using the qualitative *visual estimation of percentage volume* methodology. It is recommended that this site is revisited and assessed quantitatively once access is safely obtainable.

The proportion of pine, willow/poplar and other species in the woody debris accumulation at the bridge was visually assessed as comprising 90%, 5% and 5% respectively (Figure 42).

It is recommended that this site is revisited and assessed quantitatively once access is safely obtainable. This may be best achieved using the *wood pile – deconstruction* methodology, assuming that the woody debris is able to be safely removed and stockpiled elsewhere. In addition, given the volume and type of material present (both there and at Site 17 downstream at the coast), further investigation as to potential material sources within the Waikare River catchment is recommended.

Figure 40: View of the destroyed SH2 road bridge on the Waikare River and Site 16.

3.17 Site 17: Waikare River mouth

This site was visited on 3 March 2023 by helicopter. It has not however been included in the data presented in this report. Unfortunately, while a suitable and safe landing location was available and used, fine organic debris (consisting of grass and fine root matter) present at this site obscured the areas of accessible LWD to such a degree that the site was not able to be assessed using quantitative or qualitative methods (Figure 41).

In areas where LWD was visible (i.e., unobscured by fine debris) there was some evidence that material had been sorted by tidal action. This meant that there were accumulations (particularly to the south of the bay) where neatly packed pine LWD were lining the shore. Sampling such an area was considered to represent an inappropriate introduction of potential bias to the assessment process. This, in combination with the lack of a safe and suitable landing area for the helicopter, meant that Site 17 was not assessed (quantitatively or qualitatively).

It is recommended that this site is revisited and assessed quantitatively if tidal action removes the fine debris accumulation revealing LWD suitable for assessment, or an alternative safe landing location is found.

A local land manager was present on site and reported anecdotally that a storm during 2012 resulted in a significant amount of LWD being discharged to the coast from the Waikare River. In their own estimation, this material would have been categorised in the current assessment as cut pine. The suspected LWD sorting action performed by the tides at this location were confirmed, with the additional information obtained also suggesting that material continues to be remobilised from the beach during heavy seas. This remobilised material tends to migrate north within Hawke Bay. It could be expected therefore that Site 13 (at Mahia Beach) may receive LWD via this coastal transportation mechanism.

Figure 41: A deep layer of fine debris covered LWD accumulations at Site 17 (left) while to the south LWD of pine species origin appeared dominant (right).

3.18 Summary of LWD by species

A total of 17 sites were visited either by vehicle or helicopter between 28 February and 3 March 2023 to determine the species composition of any LWD present. Data was collected at 15 of these sites.

Of the sites visited, only 11 were safely accessible and/or suitable for undertaking quantitative assessment using either the *wood piles – hand count* or *square plot* methodologies outlined in Section 2.0. A total of 2,203 pieces of LWD were counted at these 11 sites (M = 200, SD = 126, min = 65, max = 436).

Four of the six sites that were not safely accessible and/or suitable for undertaking a quantitative assessment were assessed using the qualitative *visual estimation of percentage volume* methodology. Figure 42 presents an overview of the LWD species composition data collected at each of the 16 sites visited.

Two sites (Site 8 and Site 17) were not suitable for undertaking a quantitative or qualitative assessment and as such have been excluded from the calculation of the summary statistics. Site 8 (where no LWD accumulated) is however included in graphical depictions of data collected.

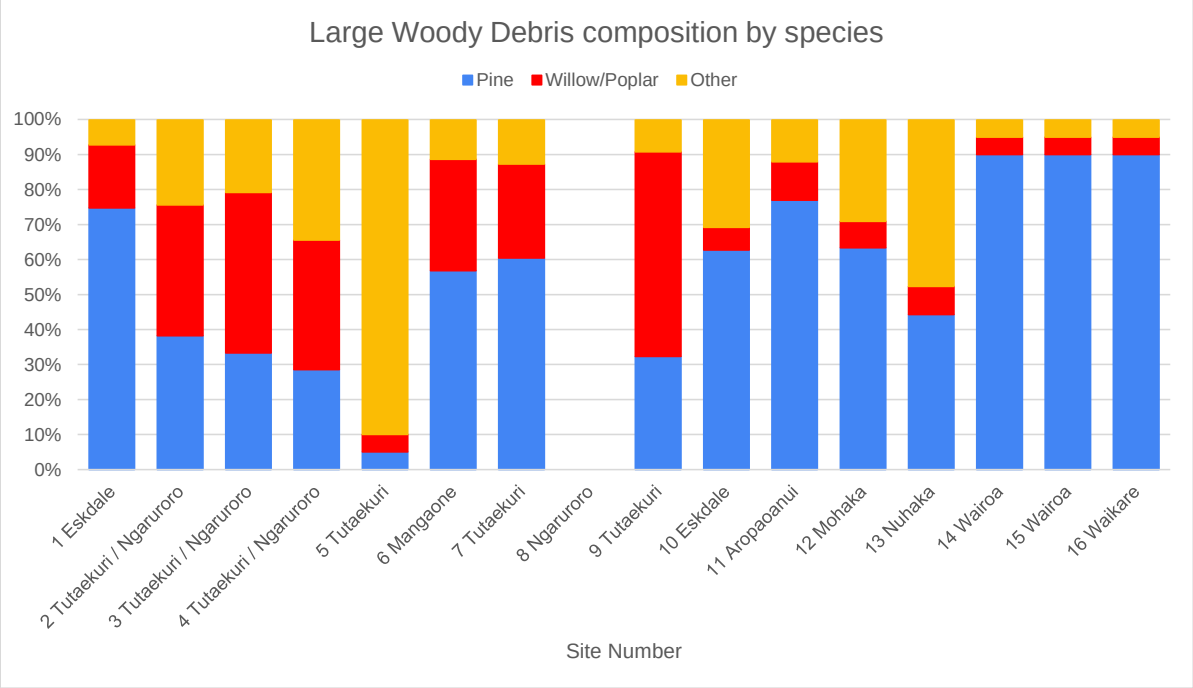

Figure 42: Large woody debris composition by species at all sites.

The proportions of LWD categorised as pine, willow/poplar or other species present at all sites ranged widely (between 5%, 0%, 0% and 90%, 58%, 90% respectively).

On average, the proportion of pine (N = 15, M = 56%, SD = 26%) present in LWD accumulations was approximately 35% higher than the proportion of either willow/poplar (N = 15, M = 21%, SD = 18%) or other species (N = 15, M = 23%, SD = 23%). On average the proportions of LWD categorised as either willow/poplar or other species each comprised approximately 20% of LWD accumulations.

3.19 Summary of LWD by assessment category

At 11 of the 17 sites visited each piece of LWD counted was assigned to one of eight categories as set out in Table 1. The aim of categorisation was to collect data that might give clues as to the ultimate origins of LWD.

The average proportions of LWD assigned to each of the eight categories at the 11 sites for which qualitative data was collected were as follows (presented in the order they appear in Figure 43 from bottom to top): pine piece (M = 37%, SD = 14%), cut pine (M = 3%, SD = 3%), windthrow pine (M = 6%, SD = 5%), long resident pine (M = 7%, SD = 9%), fresh cut pine (M = 0%, SD = 1%), willow/poplar (M = 23%, SD = 16%), windthrow willow/poplar (M = 3%, SD = 5%), and other species (M = 22%, SD = 13%).

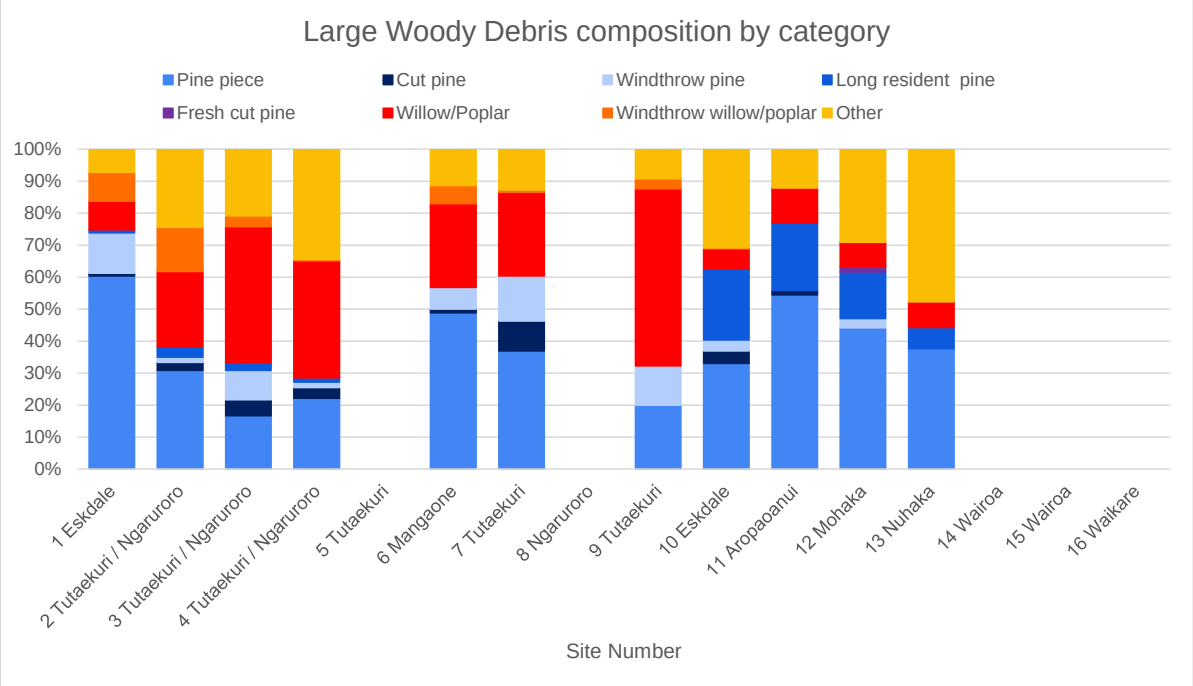

Figure 43: Large woody debris composition by category at all sites.

By far the most common category of pine species LWD recorded on average was *pine piece* (N = 11, M = 37%, SD = 14%, min = 17%, max = 60%). This LWD assessment category is defined as pieces of LWD not evidencing cut (or other) marks indicating that they have been harvested (either recently or historically). All other categories into which pine species LWD were placed averaged less than 10% across all 11 sites. Of particular note was the low contribution that *cut pine* made on average (N = 11, M = 3%, SD = 3%, min = 0%, max = 9%). It should be noted here that absence of cut (or other marks) is not absolute confirmation that LWD in this category has not originated from harvesting activity. Breakage is a common occurrence during tree felling, for example.

On average the proportion of *pine pieces* present in LWD accumulations (N = 11, M = 37%, SD = 14%, min = 17%, max = 60%) was approximately 15% higher than the proportion of either *willow/poplar* (N = 11, M = 23%, SD = 16%, min = 6%, max 55%) or *other* species (N = 11, M = 22%, SD = 13%, min = 7%, max – 48%).

On average the proportions of LWD categorised as either *willow/poplar* or *other* species each comprised approximately 22% of LWD accumulations.

3.20 Summary of LWD by estimated percentage volume

At 15 of the 17 sites visited a qualitative visual estimation of the percentage volume of pine in terms of total LWD volume was made.

The average proportions of pine species LWD by volume across all sites assessed was 56% (N = 15, SD = 32%, min = 5%, max = 90%) (Figure 44).

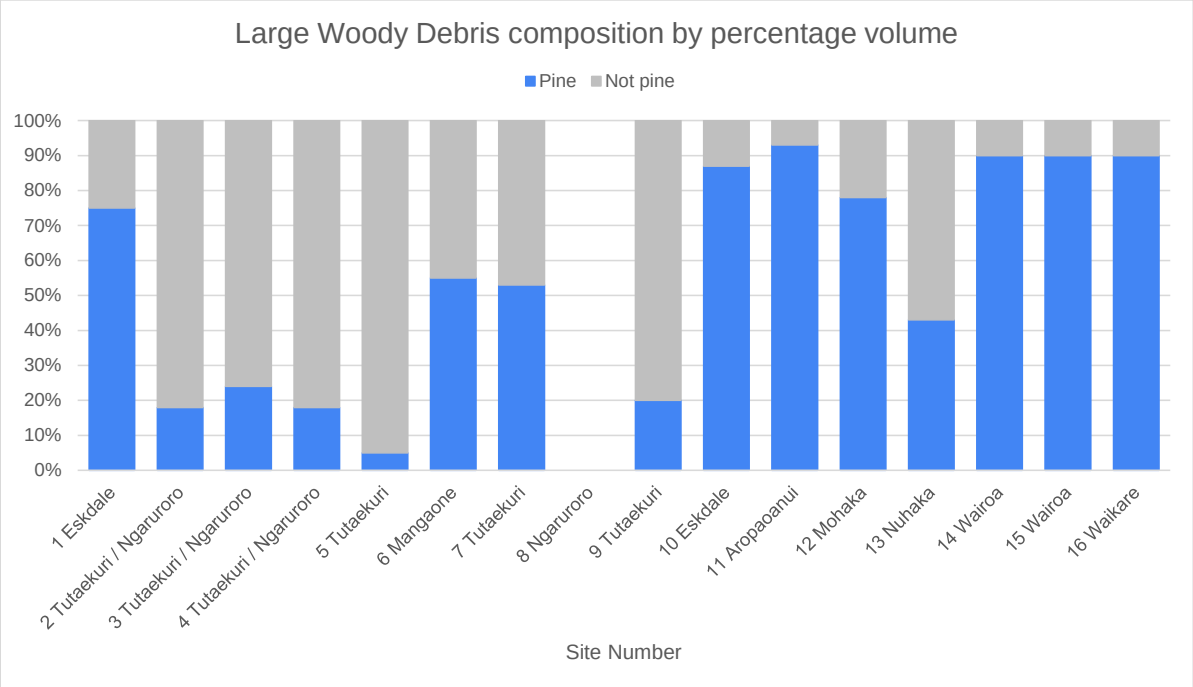

Figure 44: Large woody debris composition by percentage volume at all sites.

The figure returned via the qualitative visual assessment is similar to the quantitative LWD count data for pine species collected and presented in Figure 42 (N = 15, M = 56%, SD = 26%, min = 5%, max = 90%), suggesting that a qualitative visual estimation of percentage volume may have value as an additional LWD assessment methodology. This may be particularly valuable when time is limited (e.g., assessing multiple or remote sites via helicopter) or setting boots on the ground at assessment sites is not safe or achievable.

4.0 Conclusion

On average across the 15 sites for which data was collected the proportion of LWD of pine origin was 56% (N = 15, SD = 26%). The proportion of LWD of both willow/poplar or other species was on average 21% (N = 15, M = 21%, SD = 18% and N = 15, M = 23%, SD = 23% respectively). It is apparent from the data collected that pine was a significant contributor to LWD accumulations at the sites assessed with 75% or more of LWD at 5 sites (31%) originating from a pine source, 50% or more of LWD at 9 sites (56%) originating from a pine source, and 25% or more of LWD at 14 sites (88%) originating from a pine source. This finding is supported by the LWD percentage volume estimates which suggest that LWD accumulations at the sites assessed with 75% or more of LWD at 7 sites (44%) originating from a pine source, 50% or more of LWD at 9 sites (56%) originating from a pine source, and 25% or more of LWD at 10 sites (63%) originating from a pine source.

LWD of pine origin was allocated to one of five categories (Table 1) with the expectation that doing so could provide insight into the debris source of origin (e.g., a particular plantation forestry related activity). The average proportions of LWD assigned to each of these five categories at the 11 sites for which quantitative data was collected were as follows: pine piece (M = 37%, SD = 14%), long resident pine (M = 7%, SD = 9%), windthrow pine (M = 6%, SD = 5%), cut pine (M = 3%, SD = 3%), and fresh cut pine / post event modified logs (M = 0%, SD = 1%).

On average, the most common LWD recorded was *pine piece* (N = 11, M = 37%, SD = 14%, min = 17%, max = 60%). This category is defined as pieces of LWD not evidencing cut (or other) marks indicating that they have been harvested (either recently or historically). It is not unreasonable therefore to assume that this type of debris may have originated from trees damaged by cyclonic winds with pieces thereof subsequently entering waterways. The mechanism of delivery is potentially the same as that proposed for LWD categorised as windthrow pine discussed below.

The other four categories into which pine species LWD were placed averaged 16% in aggregate across the 11 sites assessed quantitatively. The relatively high contribution (in comparison to cut pine for example) of LWD in the windthrow pine assessment category was perhaps somewhat unexpected. Averaging 6% of LWD assessed across all sites, the presence of windthrow pine (which constitutes a tree or part thereof with the rootball attached) seems to indicate that perhaps both streambank and hillside erosion processes were a key LWD delivery mechanism during Cyclone Gabrielle.

Of particular note in terms of the scope of this assessment is the low contribution that *cut pine* made to LWD accumulations on average (N = 11, M = 3%, SD = 3%, min = 0%, max = 9%). Importantly according to the categorisation used, the LWD assessment category ‘cut pine’ took precedence over all others. That is to say that any piece of LWD of pine species origin evidencing cut or processing marks was categorised as cut pine. This was done to ensure LWD of this type (i.e., wood previously being harvested / processed in some way) was not underrepresented or diluted through inclusion in other categories.

5.0 Comparison with data collected in the Gisborne District

To provide additional context to the LWD data collected and discussed above, results from LWD assessments undertaken after two large scale storm events in the Gisborne District are presented alongside the current assessment data (Table 2).

After Cyclone Cook struck in 2017 the predominance of pine-based slash was established at multiple sites within the Gisborne District, comprising mainly abraded weathered logs lost

from stored slash piles or elsewhere within the forest boundaries (Cave at al., 2017). This early investigation into LWD also identified willows and poplars as a significant contributing factor in LWD accumulations and the associated damage caused.

Table 2: Comparison of LWD assessment results in Gisborne and Hawke's Bay.

Storm event	***Pine***	***Willow / poplar***	***Cut pine***	***Long resident pine***	***Windthrow pine***
2017 Cyclone Cook	*68 %*	*32 %*	*21 %*	*67 %*	*12 %*
2018 Queen's Birthday	*85 %*	*11 %*	*16 %*	*64 %*	*20 %*
2023 Cyclone Gabrielle[3]	*56 %*	*21 %*	*3 %*	*7 %*	*6 %*

Later, an assessment of the LWD mobilised during the 2018 Queen's Birthday Storm concluded that the types of LWD mobilised were comparable to those mobilised during Cyclone Cook a year earlier (Cave 2022b). In each event, cut pine contributed more than 15 % of LWD assessed, in comparison to the 3 % contribution established in the current assessment of LWD within the Hawke's Bay region. Of note is an observation made by Cave (2022a) that a significant number of the long resident logs assessed were originally cut logs, with a number also observed with waratah marks. These pieces of LWD would have been categorised as cut pine in the current assessment, meaning that the data presented for 2018 would likely have comprised a higher percentage of cut pine and lower percentage of long resident pine.

What the Hawke's Bay data does suggest is that the contribution of cut pine (and indeed long resident and even windthrow pine too) is significantly lower than that observed within the Gisborne District. Willow and poplar LWD on the other hand appears much more comparable between the three events for which data is presented in Table 2.

[3] Data from Hawke's Bay region collected during this LWD assessment.

6.0 Recommendations

6.1 Additional data collection

This assessment was undertaken within seven of the 12 HBRC water management catchments (Figure 1). This provided good representative coverage for areas known or thought to be subject to LWD accumulations. However, undertaking LWD assessments at sites within the Nuhaka, Waihua and Tangoio catchments (the latter falling within the Waikare water management catchment) would provide a more complete picture of LWD within the entire Hawkes Bay region. Sites to be targeted for additional LWD assessment should include both coastal and riverine sites, the latter focussing on locations at which infrastructure (e.g., bridges) are present. In this way, any differences in LWD accumulating at structures compared with LWD accumulating at the coast will be captured. As well as additional sites to be assessed, a number of sites visited during this assessment should be revisited with the aim of undertaking quantitative LWD assessments.

The degree to which LWD remains distributed within river catchments remains unknown. Regular traverses of some rivers are recommended to begin assessing the residual risk posed by LWD that remains in Hawkes Bay river systems at or below flood height level. It is possible that other agencies have already collected data that would address both of the points raised above. If so, a collaborative approach to data analysis and interpretation should be explored.

Further, it is recommended that a routine LWD monitoring / assessment protocol be established at a number of LWD assessment sites, and that these are visited after significant rainfall events likely to have mobilised LWD. It is recommended that any future LWD monitoring and assessment program follow the assessment methodology outlined by Cave (2023) for consistency between regions.

6.2 LWD origin and future risks

One of the key outcomes of this LWD assessment was to utilise, if possible, the categorisation methodology to inform HBRC as to potential sources of LWD origin. Identifying the amount of land (ha) within each water management catchment (or better yet each river catchment) with the potential to contribute LWD could be used as a starting point for assessing risk to downstream infrastructure. A second measure that could be considered is the length of river (m) adjacent to each land use type with the potential to contribute LWD. This metric may be particularly useful when addressing the LWD contribution of willow and poplar tree species.

In addition, despite cut pine not contributing significantly to the LWD accumulations assessed, a review of information pertaining to slash trap location, design, maintenance and performance is also recommended to give further insight as to the risks posed by LWD of pine species origin in the HB region.

6.3 Summary of Recommendations

1. Assessment of LWD accumulations identified at additional locations.
2. Establishment of a routine LWD monitoring / assessment protocol after storm events.
3. Identification of potential LWD contributing land uses within river catchments.
4. Assessment of forestry industry compliance with several NES-PF regulations.

7.0 References

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Cave, M. P., Davies, N., Langford, J. (2017). *Cyclone Cook Slash Investigation*. Gisborne District Council. October 2017.

APPENDIX A

Large Woody Debris Data Collected

Site #	Summary statistics - quantitative and qualitative assessments				Summary statistics - qualitative assessment	
	Pine	Willow/Poplar	Other	Pieces counted	Pine	Not pine
1	75%	18%	7%	111	75	25
2	38%	37%	24%	123	18	82
3	33%	46%	21%	120	24	76
4	29%	37%	34%	235	18	82
5	5%	5%	90%		5	95
6	57%	32%	11%	88	55	45
7	60%	27%	13%	149	53	47
8						
9	32%	58%	9%	65	20	80
10	63%	6%	31%	357	87	13
11	77%	11%	12%	347	93	7
12	63%	8%	29%	172	78	22
13	44%	8%	48%	436	43	57
14	90%	5%	5%		90	10
15	90%	5%	5%		90	10
16	90%	5%	5%		90	10
17						
Mean	56%	21%	23%	200	56	44
SD	26%	18%	23%	126	32	32
Min	5%	5%	5%	65	5	7
Max	90%	58%	90%	436	93	95
N	15	15	15	2,203	15	15

Site #	Quantitative LWD Assessment							
	Cut pine	Long resident pine	Fresh cut pine	Pine piece	Windthrow pine	Willow/poplar	Windthrow willow/poplar	Other (No ID)
1	1%	1%	0%	60%	13%	9%	9%	7%
2	2%	3%	0%	31%	2%	24%	14%	24%
3	5%	3%	0%	17%	9%	43%	3%	21%
4	3%	1%	0%	22%	2%	37%	0%	34%
5								
6	1%	0%	0%	49%	7%	26%	6%	11%
7	9%	0%	0%	37%	14%	26%	1%	13%
8								
9	0%	0%	0%	20%	12%	55%	3%	9%
10	4%	22%	0%	33%	3%	6%	0%	31%
11	1%	21%	0%	54%	0%	11%	0%	12%
12	0%	15%	2%	44%	3%	8%	0%	29%
13	0%	7%	0%	38%	0%	8%	0%	48%
14								
15								
16								
17								
Mean	3%	7%	0%	37%	6%	23%	3%	22%
SD	3%	9%	1%	14%	5%	16%	5%	13%
Min	0%	0%	0%	17%	0%	6%	0%	7%
Max	9%	22%	2%	60%	14%	55%	14%	48%
N	11	11	11	11	11	11	11	11

APPENDIX B

Large Woody Debris Assessment Guide