# Wairoa River Bed Sediment

# Report for NIWA / MWLR

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June 2023

## Executive Summary

This report provides a brief and provisional assessment of river bed sediment character in the lower Wairoa River and considers how sediment characteristics may have changed over time. Findings are based entirely on qualitative observations made during field reconnaissance in January 2023 (pre-Cyclone Gabrielle).

Gravel was observed in sections of the riverbank as far downstream as the true right bank immediately downstream from Awamate Lagoon. Gravel was not visible in any exposed bank sections farther downstream.

Occasional probing of the riverbed indicated a largely soft-bottom bed. Some gravel was evident in the vicinity of Awamate Lagoon in a water depth of approximately 3 m.

Wood present within exposed riverbank gravels was sampled for radiocarbon dating to provide an age estimate of gravel deposits observed. All deposits post-date the Holocene sea level high-stand, indicating that the river was gravel-bedded until at least ca. 3520 cal BP. Wood beneath fine grained alluvium at the neck of the Awamate palaeochannel provides a *terminus post quem* of ca. 1365 cal BP.

The lower Wairoa River has changed character from being a largely gravel-bedded system through much of the Holocene to being a fines-dominated system today. Thick overbank fine deposits and recent flood drapes along the banks, together with water clarity, indicate a high suspended sediment load. These features that are characteristic of today's river are consistent with land clearance in the catchment, and are similar to changes observed in the adjacent Waipaoa River attributed to clearance of indigenous forest on erodible terrain. However, the precise timing of these changes in the Wairoa is in need of further investigation.

## Public Summary

The Wairoa River carries large quantities of fine sediment (clays, silts and sands). This fine sediment cloaks both the bed and the banks of the river and the river appears to be mainly soft-bottomed downstream from Frasertown. The question this investigation seeks to begin to answer is whether the river has always been characterised by such large amounts of fine sediment, or whether changes in land-use in the catchment may have altered the condition of the river. This investigation used the sediments exposed in the riverbanks as a window back in time. Gravels were seen in the riverbanks as far down the river as immediately below the old river channel at Awamate (now the Awamate Lagoon), but gravels were not seen in the bank where the old Awamate channel has been plugged. Estimates of the age of these riverbank deposits was provided using radiocarbon dating of wood recovered from the base of banks at four locations along the lower Wairoa River. Preliminary findings suggest that the Wairoa River as far as Awamate was gravel-bedded until at least 3000 years ago. Wood underneath thick fines infilling the Awamate channel indicates these deposits are younger than 1365 years old. More work is needed to understand the details of these changes to the sediments in the Wairoa River, but these results are not inconsistent with the idea that land clearance and subsequent escalation of catchment erosion has contributed to the condition of the river as we see it today.

# Table of Contents

# 1. Introduction

## 1.1 Aim

The aim of this work is observe the condition of the Wairoa River bed in connection with sediment and to assess the likelihood of past change in bed condition. The broader context (outside the scope of this report) is to evaluate historical bed conditions in relation to fish habitat. The work is necessarily qualitative and provisional. A full-scale assessment of bed sediment character was not feasible within the scope of the work.

## 1.2 River types, forms and adjustment

In undertaking any assessment of river characteristics, it is important to recognise the range and diversity of river types, which reflect the prevailing controls on channel form at any given reach or segment of any given river. Figure 1 outlines a broad spectrum of New Zealand's gravel-dominated river types and summarises their controls and characteristics. It is important to note that any single river could display the range of these characteristics along its full length, from source to sea/lake. As such, it is also important to take into account catchment characteristics to understand what type of river might be expected at a given location within that catchment (section 1.3) and accordingly how changes in catchment characteristics (boundary flux conditions) may effect transformation of channel form.

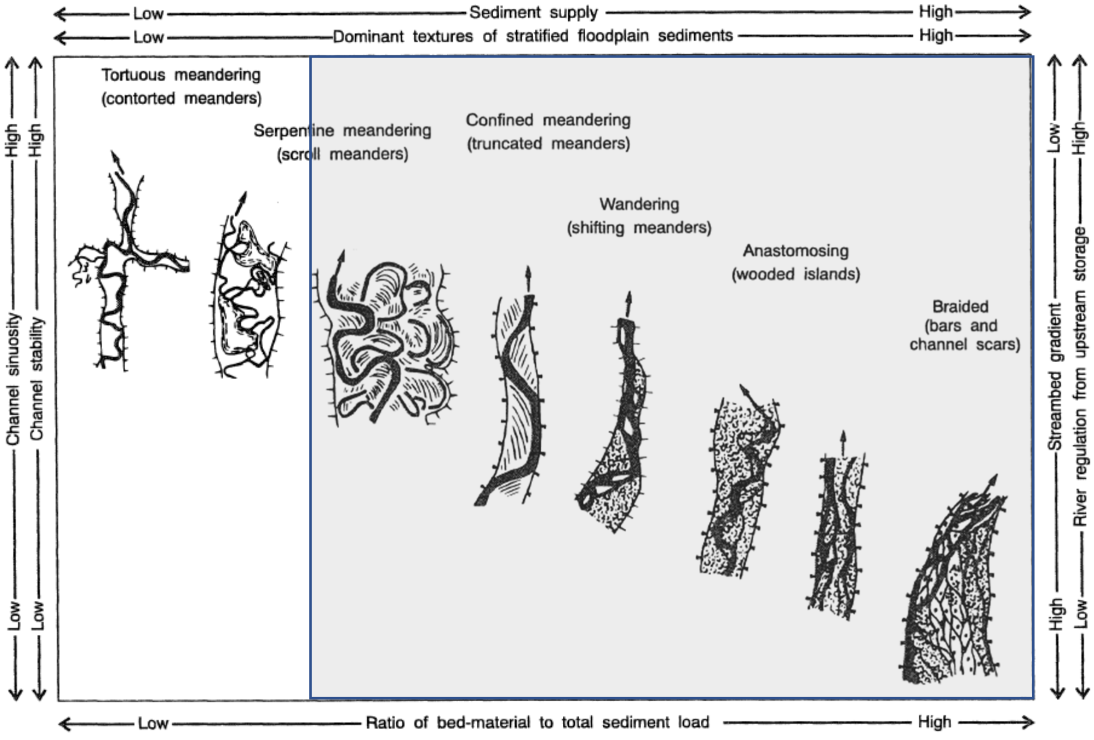

**Figure 1.** Continuum of river channel types and controlling variables, highlighting the spectrum of gravel-bed river types (shaded), after Mosley (1992). Note: sediment supply is predicated on coarse (bed calibre) material in this diagram. Large volumes of fine grained sediment can effectively overwhelm previously bedload-dominated systems, as observed in the Waipaoa (e.g. Fuller et al., 2023).

Sediment type and volume supplied plays an important role in channel form and geomorphology (Figure 1). Gravel-bed rivers are characterised by high width:depth ratios (i.e. wide and shallow), in contrast with suspended load dominated systems, where finer grained, cohesive sediments lining the channel limit lateral adjustment and generate typically low width:depth ratio channels (i.e. narrow and deep). Changing catchment sediment supply can result in transformation of river channel form since the form of the river is largely dependent on the sediments lining the channel. Over-supply of coarse, bedload calibre material will promote conditions favouring wide, shallow, gravelly channels, whilst over-supply of fine suspended results in channel narrowing. Both directions of channel form adjustment have been observed in New Zealand: the Raparapaririki River was transformed from a largely single-threaded wandering channel to a multi-threaded braided form in response to coarse sediment overload in response to catchment erosion as a consequence of Cyclone Bola (Tunnicliffe et al., 2018). In response to fine sediment overload, the upper Waipaoa (East Coast Region) has been transformed from a single-thread, clear-flowing, cobble-bedded river, to a multi-thread, sediment-laden, rapidly aggrading channel with matrix-rich gravelly beds in the upper and mid-catchment (Hamilton and Kelman, 1952, Gomez et al., 2001). The upper Waipaoa aggraded by up to 20 m over the last century (Marden, 2011). The lower Waipaoa River, once gravel-bedded and laterally active, has become fixed between cohesive, silty banks and floodplain sedimentation is dominated by rapid vertical accretion (Gomez et al., 1998). Marked increases in the supply of fine-grained sediment have resulted in reduced bankfull width and cross-section area, leading to channel contraction (Gomez et al., 2007, Gomez et al., 2009).

## 1.3 Catchment Context

Catchment context must be taken into account when assessing river characteristics. As indicated in discussion of transformation in the Waipaoa River (section 1.2), different parts of the same river will respond in different ways to the same disturbance. Figure 2 conceptualises the catchment ‘sediment conveyor’. The availability of sediment, its supply and transportability in a river shapes the channel form (Figure 1).

Sediment is sourced from two key areas in any catchment:

i. Original generation from the source, or production zone, i.e. the catchment headwaters and / or adjacent slopes that are coupled with the river channel.
ii. Reworked alluvial deposits that have been originally sourced from the production zone, but temporarily stored in river terrace and floodplain deposits in the transfer zone (Figure 2).

Reworking of gravel stores in floodplain and adjacent terraced alluvium as rivers adjust laterally makes an important contribution to the coarse load of river systems and has even been cited as contributing to planform change along some systems (Schumm, 1985). Conversely, erosion of soft-rock hill country provides an important primary source of fine sediment in many New Zealand catchments. Where a river gets its sediment from within its catchment is critical to understand its form and potential transformation of that form over time.

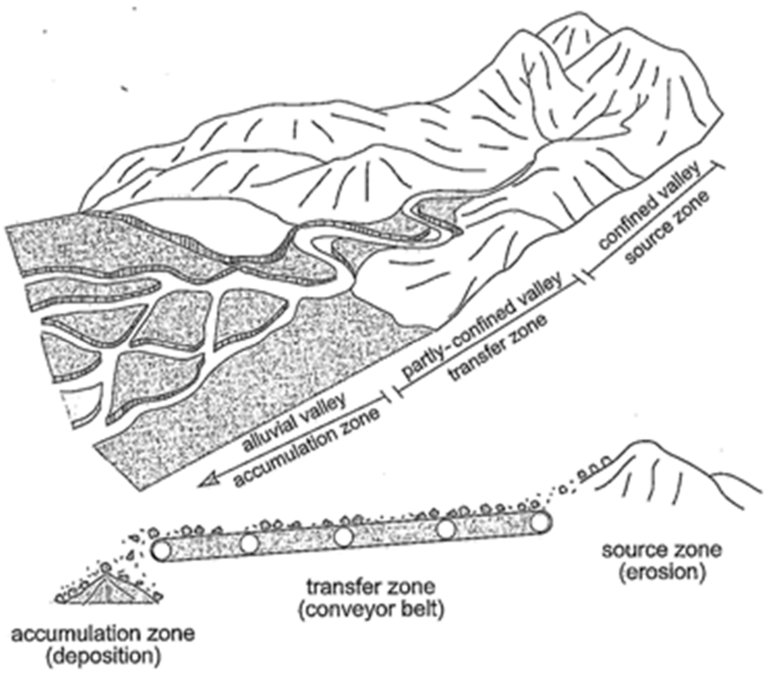

**Figure 2.** The catchment sediment conveyor (from Brierley & Fryirs, 2005).

The sediment conveyor in the transfer zone is not smooth, but jerky, which means sediment is conveyed often as a series of pulses, bedwaves, or slugs  (Nicholas et al., 1995). The nature of this transfer zone is that the river has sufficient energy (slope and discharge) to convey sediment through these reaches and that on the whole, these transfer reaches will alternate between aggradation and degradation, depending upon the jerkiness of the conveyor, reflecting sediment flux and supply both from upstream and lateral reworking of alluvial deposits. In addition, besides vertical adjustments, river reaches in this transfer zone may also adjust their form and an ‘hour-glass’ alternation may be apparent between wider, more active reaches and narrower less laterally active reaches. In rivers where the channel has the capacity to adjust (i.e. it is not confined e.g. by valley sides, terraces, or artificial constraints), more laterally active reaches may become partially or fully braided, relative to more single-threaded wandering, or meandering reaches. A range of river types (Figure 1) may therefore be expected in the transfer zone of gravel-bed rivers.

In the depositional zone, stream energy drops below gravel transport thresholds and the river lacks the power to transport the coarsest fraction of its bedload (gravel) due largely to channel gradient change. Flattening of the channel slope reduces stream energy and gravel is deposited. This point in the catchment sediment cascade is also described as the gravel-sand transition, because downstream from this point, the river is only competent to transport sand size material (Figure 3). The lower Wairoa River is likely to sit at this transition from transfer to depositional zone within the catchment, or entirely within the depositional zone given its proximity to the river mouth. Gravel may therefore be naturally absent in the lower courses of otherwise gravelly rivers: the Manawatu River, for example, lacks the energy to transport gravel to the coast and deposits its gravel load at Opiki (Page and Heerdegen, 1985).

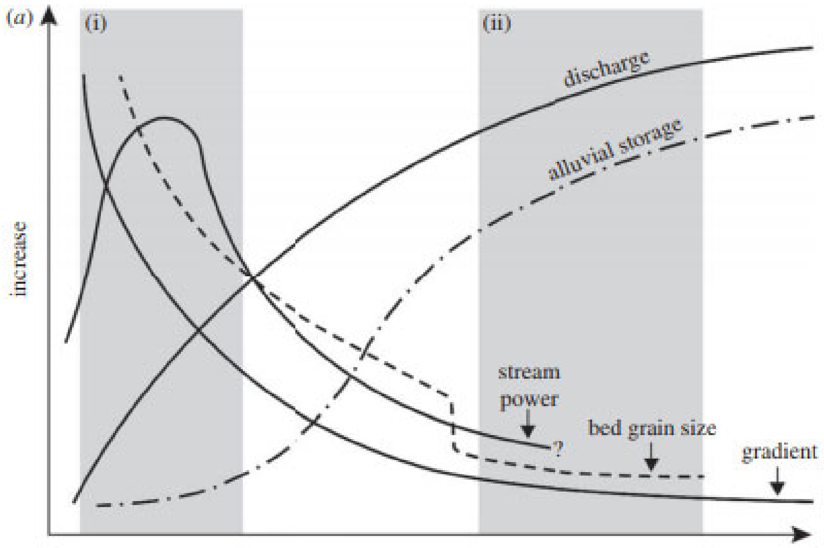

**Figure 3.** River system attributes in relation to drainage area, the gravel-sand transition is defined as the abrupt change in bed grain size, reflecting critical reduction in gradient and stream power at this point in the catchment (from Macklin et al., 2012).

## 2. Assessment of sediment characteristics

Observations of sediment characteristics in the lower Wairoa River were made with reference to visible bank exposures and probing of the bed (where feasible) in the length of river indicated in Figure 4. This assessment was done from a boat on 19 January 2023. A series of photographs in Figure 5 provides an assessment of typical exposed bank sections along this length of river. All photos dated 19 January 2023. Gravel is visible at the base of banks at sites 1-3, 5, 8-9 (cf. Figures 4 & 5). A digital elevation model (DEM) of the lower Wairoa derived from LiDAR imagery helps to provide some further geomorphic context for these sites (Figure 6).

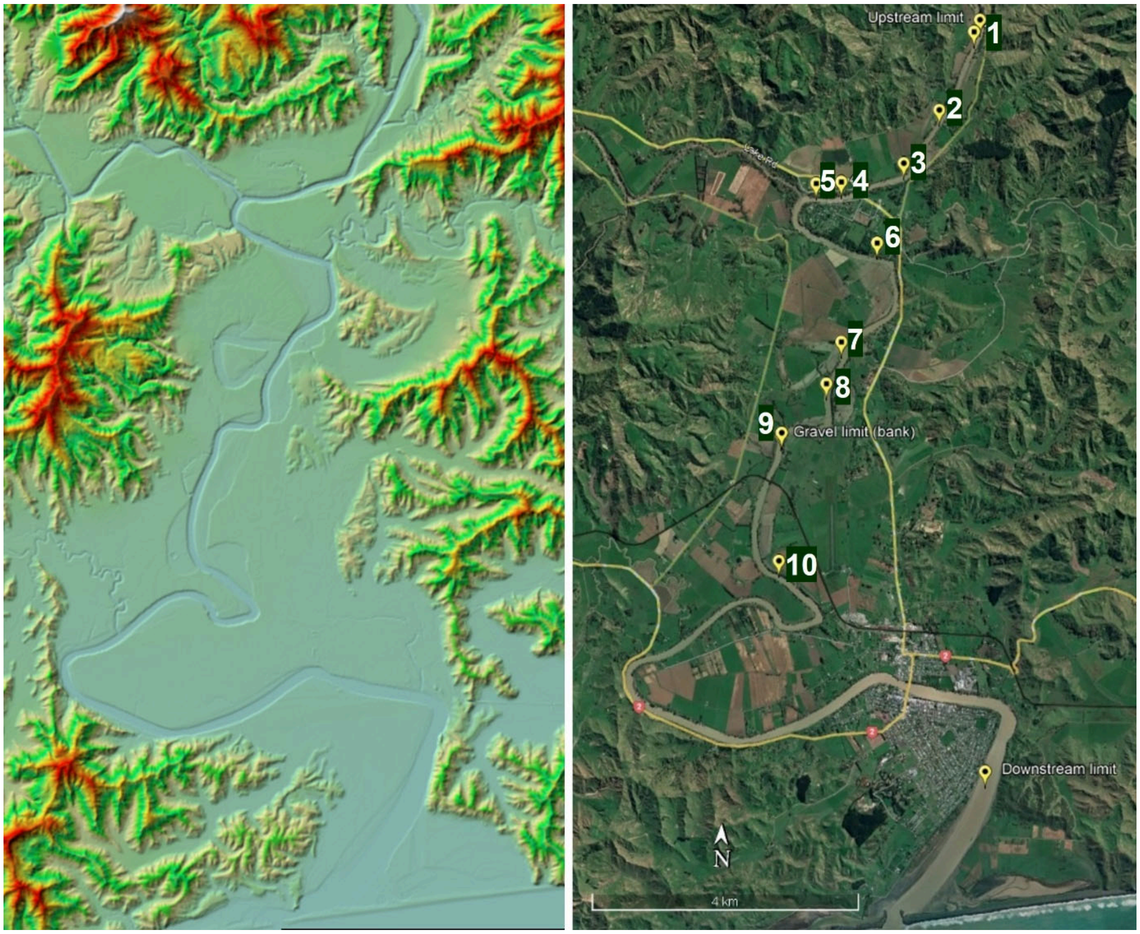

**Figure 4.** Length of lower Wairoa River assessed on 19 January 2023 (image provided by NIWA). Left: LiDAR-derived DEM; right: aerial imagery April 2022 (Source: Google Earth).

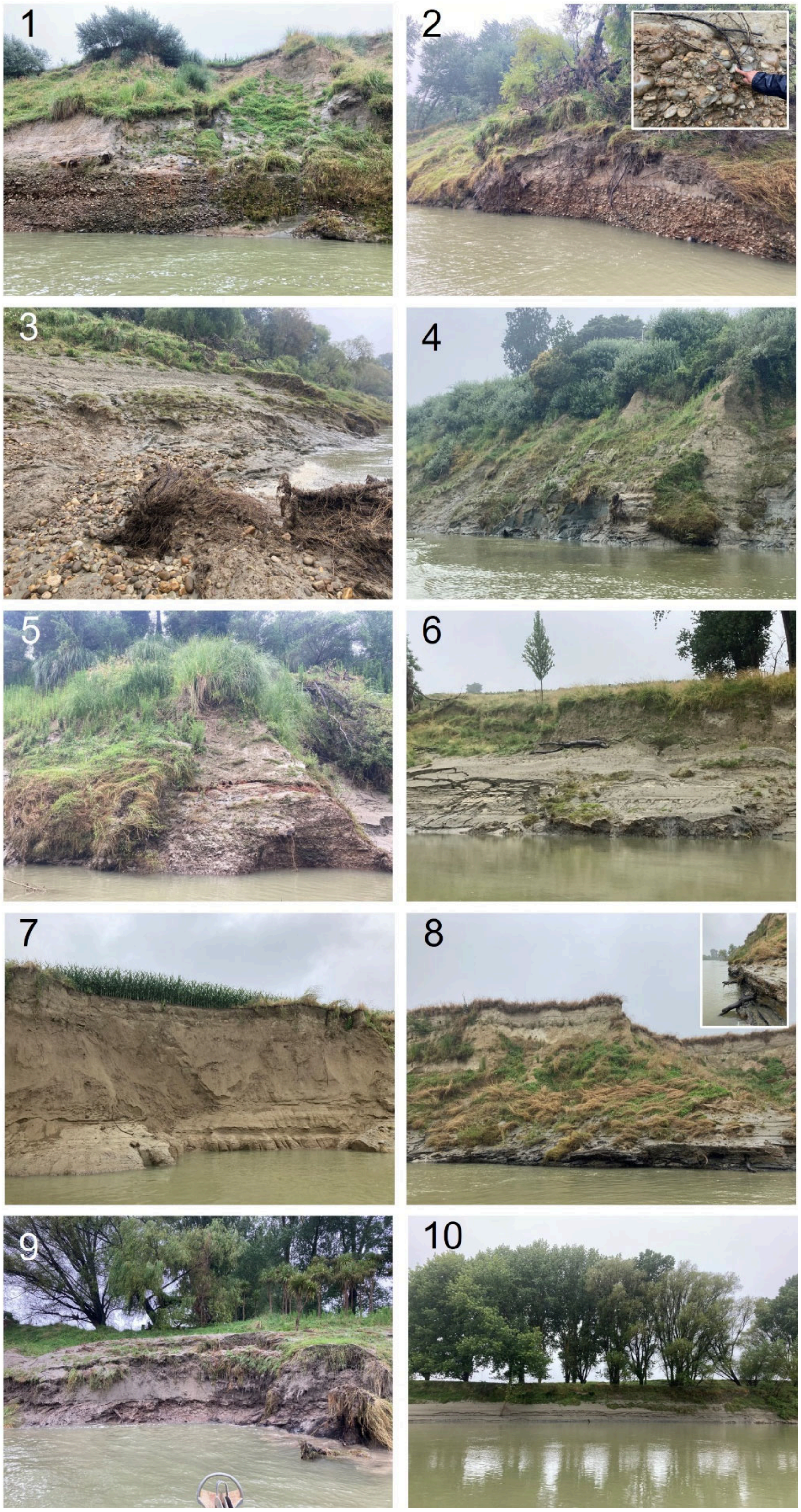

**Figure 5.** Exposed bank sections, lower Wairoa, progressing from upstream to downstream (cf. Figure 4). Gravel is visible at sites 1-3, 5, 8-9.

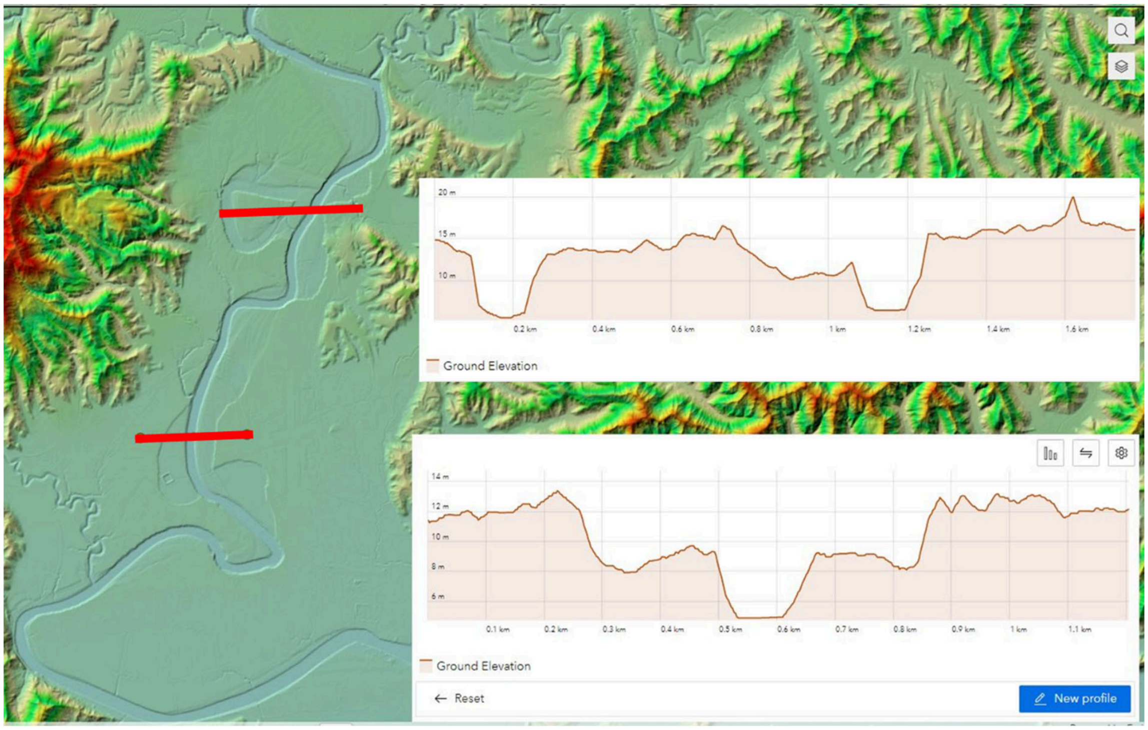

**Figure 6.** LiDAR-derived DEM of lower Wairoa River, with selected cross-sections illustrating floodplain and valley floor topography, highlighting the presence of lower elevation fine-grained benches inset below the level of the floodplain. The upper section shows relief across the apex of a palaeochannel at Awamate lagoon.

## 3. Age of deposits

*In situ* wood preserved within or directly below gravels exposed in the floodplain along the lower Wairoa River was sampled to assess the age of gravels observed in the lower river in the vicinity of sites 1, 5 and 8 (Figures 4 & 5). Exposed *in situ* wood was also sampled beneath fine grained alluvium in the vicinity of site 7 (cf. Figures 4 & 5) to assess the age of apparently more recent fine-grained sedimentation in the river infilling the Awamate paleochannel. The context of each radiocarbon sample site is given in Figure 7. Samples were processed at Waikato Radiocarbon Dating Laboratory and results of the $^{14}C$ analyses are provided in Table 1. Radiocarbon age determination reports are included in an Appendix to this report. Note: WR-2 was a duplicate sample at site 1 and not submitted for analysis.

**Figure 7.** Wood sampled for radiocarbon dating in the lower Wairoa River. The location of each sample is marked with an 'x'. Samples WR-1, WR-3 and WR-5 were all collected from basal gravels in the river bank exposure. Sedimentology of the lower bank from which sample WR-5 was collected (horizontally-bedded clay or silt rich fine deposits, layered wood and interdigitating gravels – inset) strongly suggests an estuarine environment. Sample WR-4 was collected from wood underlying sandy alluvium at the neck of the Awamate paleochannel. Details of the radiocarbon ages are provided in Table 1.

**Table 1.** AMS radiocarbon ages, Wairoa River

| **Sample** | **Lab Code** | **Site** (Figs 4 & 5) | **$^{14}$C date yr BP** (±1σ) | **Cal. yr BP** (±2σ) | **Material** |
|---|---|---|---|---|---|
| WR-1 | Wk-56419 | 1 | 5698 ± 16 | 6390-6500 | Wood |
| WR-3 | Wk-56420 | 5 | 3558 ± 18 | 3690-3890 | Wood |
| WR-4 | Wk-56421 | 7 | 1539 ± 18 | 1310-1420 | Wood |
| WR-5 | Wk-56422 | 8 | 3355 ± 18 | 3450-3590 | Wood |

# 4. Discussion & Conclusions

Following the naming convention suggested by Fryirs and Brierley (2018), the Wairoa River in the lower reach assessed (Figure 4) can be considered a partly confined, planform controlled, low sinuosity, discontinuous floodplain, sand-bedded channel. The river channel is entrenched within its floodplain, with inset benches set below the floodplain surface at certain locations (cf. Figure 6). Gravel was not observed in any exposures of the inset benches, or at the neck of the Awamate palaeochannel (sites 10 and 7 respectively, Figures 4 and 5). In the vicinity of Frasertown the river appears to have cut into underlying mudstone (site 4). Thickness of fine sediment (sands, silts) overlying gravel layers observed in bank sections appears to increase downstream (compare sites 1 and 8, Figure 5).

The presence of gravel deposits exposed in bank sections in the Wairoa floodplain, but its absence from inset units, or in the infilled Awamate palaeochannel, strongly suggests a change in river character from a gravel-bedded system to its present entrenched soft-bottom. Deposition of thick fine sediment (several metres, but not measured directly) above gravel deposits indicates transport of a large suspended sediment load. The present suspended sediment yield of the Wairoa River is 921,394 t yr$^{-1}$, which equates to a specific yield of 509 t km$^{-2}$ yr$^{-1}$ (Hicks et al., 2011). An oversupply of fine sediment from the Wairoa catchment is likely to contribute to a change in the form and character of the lower Wairoa River in ways that have been documented in the nearby Waipaoa River (section 1.2). Infilling of the lower floodplain by thick drapes of fine sediment supplied by the catchment has likely reduced the lateral mobility of the river because cohesive fine sediments are more resistant to bank erosion than non-cohesive, loose gravels. It is possible that some parts of the upper lower Wairoa River (where gravel has been observed in the banks) were once more laterally active and may have been more sinuous than its present course, being less restricted by thick fine deposits. This greater degree of activity and higher sinuosity is perhaps indicated by the Awamate palaeochannel / lagoon. However gravel was not visible in the banks of the lower reaches of the Wairoa River (downstream from site 9, cf. Figure 4) and it is unlikely that the Holocene river in these lowermost reaches was ever gravel-bedded here. The question remains as to when changes to a fines-dominated system occurred, as discussed below.

It should be noted that the lower course of the Wairoa is approaching the base level of its river mouth and as such may lack the competence to transport gravel through this lower reach at today's present river gradient (not assessed). Evidence presented by Ota et al. (1989) indicates that a site adjacent to Frasertown is at the extreme inland limit of the marine depositional influence when sea level reached the Holocene high-stand around 7500 yr BP (Clement et al., 2016). The lower Wairoa has since infilled with alluvial sediment and Ota et al. (1998) also note evidence for subsidence in the lower valley and coastal plain. The question is whether this infilling was accomplished by a gravelly river or a fines-dominated system.

Radiocarbon ages of wood collected from the lower Wairoa River (Table 1) help address the question of the nature of the Wairoa River and its potential transformation. Radiocarbon ages younger than the Holocene sea level high-stand would suggest that the river was gravel-bedded during at least some of this period of infilling. Ages older than the high-stand would indicate that the gravels relate to an older Wairoa system, most likely moving gravel through this part of its valley when sea levels were lower in the postglacial period. If the latter was the case, the transformation of the lower Wairoa to its current character is perhaps less dramatic. When interpreting radiocarbon ages from wood in alluvium, it should be remembered that these do not provide direct dating of the sediment deposits, but estimate maximum age because large pieces of wood (logs) can be reworked in the channel system and the age of the deposit in which they sit may be younger than the $^{14}$C age of the log that records tree death. All of the wood sampled in the lower Wairoa River is younger than the Holocene sea level high-stand of ~7500 yr BP (Table 1), which suggests the lower Wairoa River was gravel-bedded as it prograded following the high-stand, further supported by interdigitating gravels with apparently estuarine muds at site 8 (WR-5, ca. 3520 cal BP). Substantial thicknesses of fines have infilled the Awamate palaeochannel (site 7) in the last thousand years (WR-4, Table 4), which is commensurate with landscape transformation in the catchment and the modern river moves substantial volumes of fine sediment (cf. Hicks et al., 2011). Further work is needed to elucidate the history of Awamate infilling and the period of time over which this occurred. Coring of the deposit may yield finer grained organic material that provides a more precise assessment of age, compared with the *terminus post quem* provided by the basal wood.

## 5. Recommendations

Further work is needed to understand the history of the lower Wairoa valley. The provenance and age of fine-grained alluvium infilling the Awamate palaeochannel, as well as that which forms the inset benches adjacent to the contemporary channel, should be investigated. It is most likely that these (Awamate and bench) deposits record the most recent response of the Wairoa to change in boundary flux conditions associated with land-cover change in the catchment post-European and post-Polynesian settlement, as has been observed elsewhere (Richardson et al., 2014).

Fine sediments overlying gravels in the lower valley should also be investigated for provenance and age. It is likely that these deposits record background (pre-human disturbance) levels of catchment erosion. Their thickness is indicative that background rates of sedimentation may be naturally high, which is not surprising since the Wairoa drains a significant area of soft-rock hill country.

Recommended investigations should make use of exposed bank exposures along the Wairoa River, as well as consider a more spatially extensive campaign of subsurface measurements via coring and ground penetrating radar (GPR) to assess stratigraphy and sedimentology of the distal floodplain. Subsurface investigations would help to answer questions of the lateral extent of gravels evident in exposed banks, which could be inset units within the macro channel as opposed to laterally continuous floodplain units.

## Acknowledgements

Thanks to Dr Sandy Elliott (NIWA) for logistics, setting up the field day, and the invitation to undertake this work. Aleki Taumoepeau (NIWA) is thanked for providing the boat and his work as skipper on the day. Katarina Kawana (Ngāti Kahungunu) acted as local guide for Te Wairoa and her time and commitment is most appreciated. Hawkes Bay Regional Council provided access to preliminary LiDAR data on which DEMs in this report (supplied by NIWA) are based.

Professor Ian Fuller
21 June 2023

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# Appendix: Radiocarbon Dating Laboratory Reports

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## *Radiocarbon Dating Laboratory*

Friday, 2 June 2023

### *Report on Radiocarbon Age Determination for Wk- 56419*

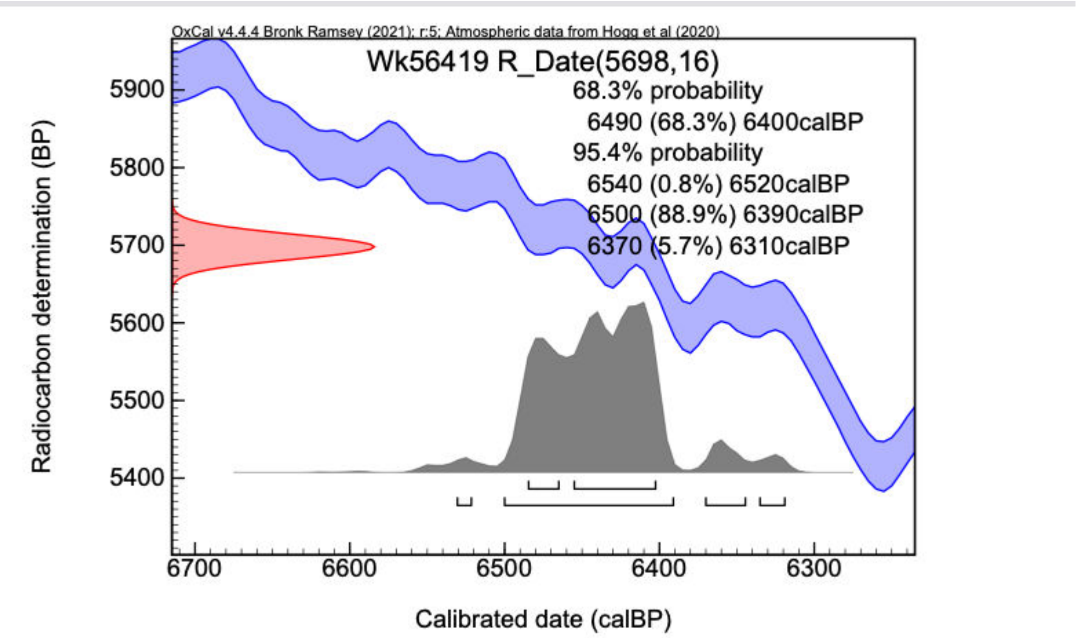
| | |
|---|---|
| **Submitter** | I Fuller |
| **Submitter's Code** | WR-1 |
| **Site & Location** | Wairoa River, New Zealand |
| **Sample Material** | Wood (branch) |
| **Physical Pretreatment** | Sample cleaned and ground. |
| **Chemical Pretreatment** | Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried. |

| | |
|---|---|
| $D^{14}C$ | -508.0 ± 1.0 ‰ |
| $F^{14}C\%$ | 49.2 ± 0.1 % |
| **Result** | **5698 ± 16 BP** |

( AMS measurement )

## Comments

Please note: The Carbon-13 stable isotope value ($\delta^{13}C$) was measured on prepared graphite using the AMS spectrometer. The radiocarbon date has therefore been corrected for isotopic fractionation. However the AMS-measured $\delta^{13}C$ value can differ from the $\delta^{13}C$ of the original material and it is therefore not shown.



- Explanation of the calibrated Oxcal plots can be found at the Oxford Radiocarbon Accelerator Unit's calibration web pages (http://c14.arch.ox.ac.uk/embed.php?File=explanation.php)
- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
- The isotopic fractionation, $\delta^{13}C$ , is expressed as ‰ wrt PDB and is measured on sample $CO_2$.
- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*.

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## *Radiocarbon Dating Laboratory*

Friday, 2 June 2023

## *Report on Radiocarbon Age Determination for Wk- 56420*

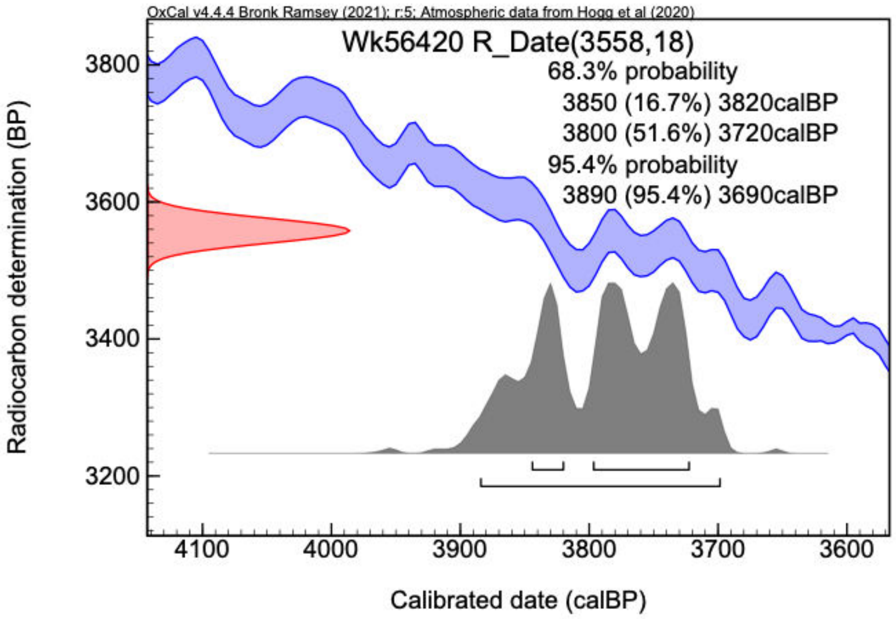
| | |
|---|---|
| **Submitter** | I Fuller |
| **Submitter's Code** | WR-3 |
| **Site & Location** | Wairoa River, New Zealand |
| **Sample Material** | Wood (branch) |
| **Physical Pretreatment** | Sample cleaned and ground. |
| **Chemical Pretreatment** | Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried. |

| | | |
|---|---|---|
| $D^{14}C$ | -357.9 ± | 1.4 ‰ |
| $F^{14}C\%$ | 64.2 ± | 0.1 % |
| **Result** | **3558 ± 18 BP** | |

( AMS measurement )

### Comments

Please note: The Carbon-13 stable isotope value ($\delta^{13}C$) was measured on prepared graphite using the AMS spectrometer. The radiocarbon date has therefore been corrected for isotopic fractionation. However the AMS-measured $\delta^{13}C$ value can differ from the $\delta^{13}C$ of the original material and it is therefore not shown.



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- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
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- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*.

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## *Radiocarbon Dating Laboratory*

Friday, 2 June 2023

### *Report on Radiocarbon Age Determination for Wk- 56421*

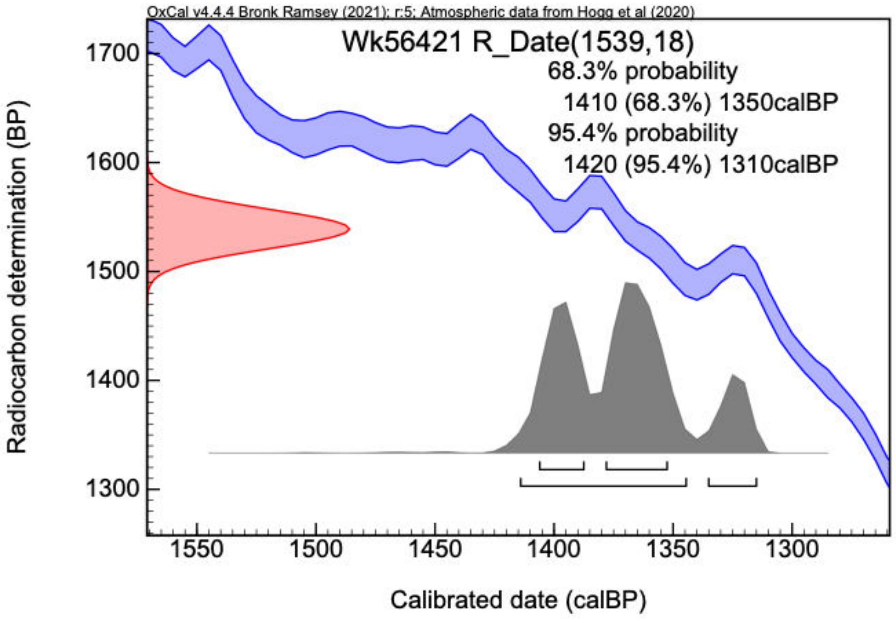
| | |
|---|---|
| **Submitter** | I Fuller |
| **Submitter's Code** | WR-4 |
| **Site & Location** | Wairoa River, New Zealand |
| **Sample Material** | Wood (branch) |
| **Physical Pretreatment** | Sample cleaned and ground. |
| **Chemical Pretreatment** | Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried. |

| | | |
|---|---|---|
| $D^{14}C$ | -174.3 ± | 1.9 ‰ |
| $F^{14}C\%$ | 82.6 ± | 0.2 % |
| **Result** | **1539 ± 18 BP** | |

( AMS measurement )

**Comments**

Please note: The Carbon-13 stable isotope value ($\delta^{13}C$) was measured on prepared graphite using the AMS spectrometer. The radiocarbon date has therefore been corrected for isotopic fractionation. However the AMS-measured $\delta^{13}C$ value can differ from the $\delta^{13}C$ of the original material and it is therefore not shown.



- Explanation of the calibrated Oxcal plots can be found at the Oxford Radiocarbon Accelerator Unit's calibration web pages (http://c14.arch.ox.ac.uk/embed.php?File=explanation.php)
- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
- The isotopic fractionation, $\delta^{13}C$ , is expressed as ‰ wrt PDB and is measured on sample $CO_2$.
- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*.

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## *Radiocarbon Dating Laboratory*

Friday, 2 June 2023

### *Report on Radiocarbon Age Determination for Wk- 56422*

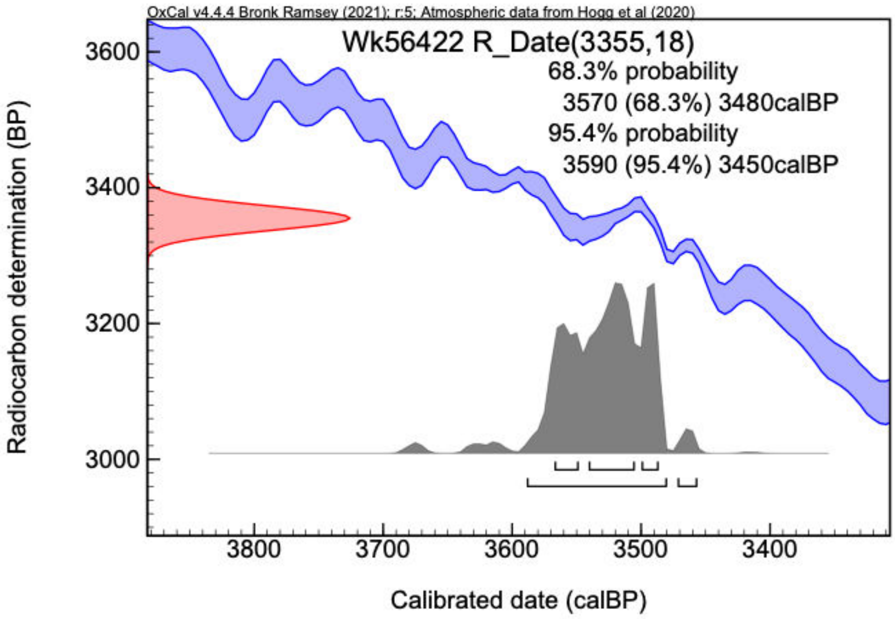
| | |
|---|---|
| **Submitter** | I Fuller |
| **Submitter's Code** | WR-5 |
| **Site & Location** | Wairoa River, New Zealand |
| **Sample Material** | Wood (branch) |
| **Physical Pretreatment** | Sample cleaned and ground. |
| **Chemical Pretreatment** | Sample washed in hot HCl, rinsed and treated with multiple hot NaOH washes. The NaOH insoluble fraction was treated with hot HCl, filtered, rinsed and dried. |

| | | |
|---|---|---|
| $D^{14}C$ | -341.4 ± | 1.5 ‰ |
| $F^{14}C\%$ | 65.9 ± | 0.1 % |
| **Result** | **3355 ± 18 BP** | |

( AMS measurement )

**Comments**

Please note: The Carbon-13 stable isotope value ($\delta^{13}C$) was measured on prepared graphite using the AMS spectrometer. The radiocarbon date has therefore been corrected for isotopic fractionation. However the AMS-measured $\delta^{13}C$ value can differ from the $\delta^{13}C$ of the original material and it is therefore not shown.



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