VISION CONSULTING ENGINEERS

Hydrological Summary

Taumārere Catchment
Nature-Based Solutions Feasibility Study

Prepared For:

Northland Regional Council

July 2025

Preface

The **Taumārere Hydrological Catchment**, encompassing the Upper Kawakawa River area, faces significant environmental challenges, including persistent flooding impacting communities and critical infrastructure, along with degraded water quality, erosion, and biodiversity loss. This comprehensive feasibility study was initiated to understand the opportunities and constraints for implementing **Nature-based Solutions (NbS)** and restoration to address these issues. This project was supported by funding from the **Ministry for the Environment's (MfE) NbS for Flood Mitigation Programme**. The project's overarching ambition is to provide a foundational blueprint to guide future restoration, with its process and outcomes having the potential for replication across Northland and wider Aotearoa New Zealand.

This study employs a multi-faceted and integrated approach, **combining advanced scientific analysis with deep community and cultural engagement**. It has systematically moved through phases involving extensive consultation with iwi, notably **Ngāti Hine**, and utilised **high-resolution GIS mapping** and **hydrological analysis** to identify and prioritise suitable NbS sites, alongside assessing **financial viability** and developing robust **monitoring frameworks**. This collaborative and data-driven methodology helps ensure solutions are culturally aligned, **ecologically sound**, and **financially sustainable**, ultimately aiming to reduce flood risk, improve water quality, enhance ecological health, and strengthen community resilience and cultural well-being.

This phase one report focuses on the drivers of the **hydrological regime** and understanding the baseline conditions prevalent in the catchment. Hydrological analysis looked at long-term hydrometric gauging data to establish the **historical** and **seasonal trends** for rainfall and river flow. The report discusses how NbS can be used to buffer and improve the catchment's hydrological response to rainfall, potentially **reducing flooding and waterborne contamination**.

Taumārere Catchment Nature-Based Solutions Feasibility Study
Hydrological Summary

First Edition

This report has been prepared by Vision Consulting Engineers Limited (VISION) based on the agreed scope of our engagement for this hydrological summary. It is intended for the use of our Client, Northland Regional Council, and for broader dissemination to inform wider stakeholders and the public on the findings related to the Taumārere Hydrological Catchment and Nature-Based Solutions project.

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CONTENTS

Executive Summary

This document provides a practical hydrological data summary for the **Taumārere Hydrological Catchment**, with a focus on **rainfall patterns, flow behaviour,** and **seasonal trends** over the past 30 years. It forms a technical evidence base to support **Nature-based Solutions (NbS)** planning, monitoring, and restoration design across the catchment.

Drawing on **long-term rainfall and streamflow records**, the report highlights key patterns — including shifting seasonal rainfall timing, increasing rainfall intensity, and **rising variability** across wet and dry years. These trends have direct implications for flood risk, baseflow reliability, sediment generation, and habitat connectivity.

The analysis includes **seasonal** and **event-based thresholds**, linking observed changes to on-the-ground risks such as erosion, sediment mobilised from gravel roads, flash flooding, and **disrupted tuna migration**. The findings are grounded in recent community observations and flood histories from Moerewa, Ōtiria, and surrounding areas.

This report supports Phase 1 of the broader NbS project, informing **catchment-scale planning** and guiding where and when restoration may support the reduction of flood peaks, protect water quality, and **support ecological and cultural outcomes**.

Key Themes and Findings

Hydrological Resilience

- Long-term rainfall and flow analysis reveals increased seasonality, intense rainfall clustering, and declining summer baseflows, indicating the role of NbS for buffering flood peaks, supporting dry-season flows, and improving catchment-scale water resource management.

Water Quality & Sediment Control

- High-frequency rainfall analysis shows year-round sediment mobilisation from gravel roads and tracks, particularly during low–moderate intensity events. NbS can be applied to reduce first-flush contaminants and long-term sediment loads.

Biodiversity & Habitat Recovery

- Seasonal rainfall shifts, prolonged dry periods, and erratic storm pulses affect tuna migration, aquatic habitat connectivity, and riparian zone stability. NbS can be strategically timed and placed to maintain critical habitat flows, improve refuge conditions, and enhance longitudinal connectivity.

Cultural Values & Mātauranga Māori

- Seasonal patterns and observed changes have cultural significance especially for tuna harvesters and repo (wetland) kaitiaki (guardians). Aligning ecohydrological insights with mātauranga Māori (Māori knowledge) supports culturally grounded restoration priorities and informs flow-related environmental indicators.

Monitoring for Funding Confidence

- Data trends from 1906–2025 establish a baseline to evaluate climate resilience, inform thresholds for flood/drought events, and justify restoration investment. Integrating these insights into the NbS monitoring framework can inform funder decisions and catchment interventions.

Community-Led Implementation

- The rainfall and flow analysis helps guide community planting, fencing, and site preparation. Sharing this knowledge informs catchment groups, landowners, and iwi to act with confidence and coordination.

Strategic Alignment and Opportunity

This hydrological assessment **supports national and local priorities** by grounding NbS in **environmental evidence**. It aligns with the **National Policy Statement for Freshwater Management (NPS-FM 2020)** and **Te Mana o te Wai**, while responding directly to the Taumārere catchment's challenges: **sedimentation, flooding, degraded habitat**, and **declining water quality.**

NbS techniques such as wetland restoration, riparian planting, and afforestation are well-supported by central funding strategies focused on **climate resilience, biodiversity recovery**, and **mātauranga Māori**. The **leadership of Ngāti Hine and local restoration groups** adds cultural momentum.

Together, these factors position the Taumārere catchment as a national pilot for co-designed, place-based NbS. The next step is delivery — **securing investment, supporting site-level action, and embedding shared governance to sustain long-term outcomes**.

1 Introduction

This report links the hydrological baseline conditions of the **Taumārere catchment to the potential use of Nature-Based Solutions (NbS) in the context of the feasibility study**. The project assesses how rainfall, river flow, sediment transport, and tidal influence interact to shape habitat, flood risk, and restoration opportunities. It builds on recent flood infrastructure investments in Ōtiria, Moerewa, and Kawakawa, while extending the focus toward long-term ecological and hydrological resilience.

Analysis is grounded in long-term data from the Waiharakeke Stream and local rain gauges and is heavily shaped by engagement with **Ngāti Hine**, who emphasise the cultural, ecological, and **mahinga kai** (cultivated food) importance of flow regimes—particularly for **tuna** (longfin eel) and **inanga** (whitebait). Long-held cultural and mahinga kai practices are adapting to shifting climate conditions, with seasonal patterns now said to occur later in the year than in previous decades.

"The realities of living in Northland's most flood-prone town, Moerewa" (RNZ, 2024a) shows the importance of analysing flood events that cause significant disruption to life in the Taumārere hydrological catchment.

Key areas of focus include:

- **Characterising catchment hydrology**: seasonal rainfall–runoff relationships, baseflow stability, and flood recession timing
- **Identifying ecohydrological thresholds**: including low flows and flood pulses critical to species migration and wetland function
- **Understanding water quality dynamics**: with attention to sediment and E. coli loading during storm events and post-harvest forestry periods
- **Linking hydrology to NbS**: identifying where flow variability, floodplain disconnection, and erosion hotspots can be addressed using nature-based interventions
- **Integrating community knowledge**: ensuring locally grounded, inclusive restoration planning that supports Te Mana o te Wai and catchment wellbeing

The report recognises that **NbS offer more than flood mitigation**—they are a pathway to water quality improvement, cultural reconnection, and system-wide ecological renewal (Harmsworth, 2013). The approach draws on the **flood pulse concept**—the dynamic patterns of the rise and fall of flows that underpin habitat complexity and sediment transport cycles.

1.1 Objectives

This ecohydrological assessment aims to support the development of NbS strategy within the Taumārere catchment by providing clear, data-driven insights into hydrological processes, ecological flow thresholds, and restoration potential. The specific objectives are to:

- **Characterise the hydrological setting**
  Analyse long-term flow and rainfall data to establish baseline seasonal patterns, flood pulse dynamics, and recession behaviour in the Taumārere catchment.
- **Identify ecohydrological thresholds and species requirements**
  Derive key flow metrics (e.g., Q95 as a low-flow indicator, FRE3 for flushing flows, POT for peak-over-threshold events) relevant to aquatic habitat function and life-cycle support for species such as tuna, inanga, and other taonga (sacred) or indicator species.
- **Assess sediment and water quality behaviour**
  Examine how rainfall and flow variability influence sediment transport and E. coli loading, particularly in relation to forestry operations, rural land use, and event-scale runoff.

- **Evaluate climate change implications**
  Consider how projected changes in rainfall patterns and seasonal water availability may affect flow regimes, habitat conditions, and future restoration planning under climate variability.
- **Inform NbS planning and prioritisation**
  Identify where natural hydrological processes could be harnessed or restored through NbS—such as floodplain reconnection, wetland buffering, sediment interception, or riparian enhancement.
- **Support community-informed and culturally grounded restoration**
  Integrate wānanga (workshop) insights and local observations—especially from Ngāti Hine—to reflect community priorities, support ***Te Mana o te Wai***, promote sustainable aspirations, and collaborative outcomes.

1.2 How to Use This Report

This document is designed to support interpretation of flow dynamics, ecological thresholds, and potential restoration interventions in a way that is accessible to technical staff, planners, and community partners.

The report sequence follows this logic:

- **Catchment Characteristics →** the topography, soils, land use, and geology that shape hydrological behaviour and restoration potential.
- **Rainfall →** the primary climatic input driving catchment response.
- **Flow →** the river's hydrological response, including thresholds and seasonality.
- **Flood Recession →** the return to baseflow, and its relevance to flood risk, habitat and sediment exposure.
- **Water Quality →** event-driven transport of sediment and E. coli linked to land use and rainfall.

The analysis also highlights flow-related indicators that may support **future monitoring, climate adaptation planning**, or **engagement with tangata whenua** (established inhabitants) and **local landowners** for NbS projects (Figure 1).

Brief Note on Limitations: This report provides a catchment-scale interpretation of available hydrological data and ecological flow patterns, often measured at the downstream extremity of the catchment rather than in the remote upper catchment. While it supports early-stage planning and prioritisation of NbS and restoration, it is not intended to replace site-specific investigations. Localised assessments may be required where sensitive receptors (e.g., buildings, lakes, critical infrastructure) are present or where proposed interventions may significantly alter local hydrology.

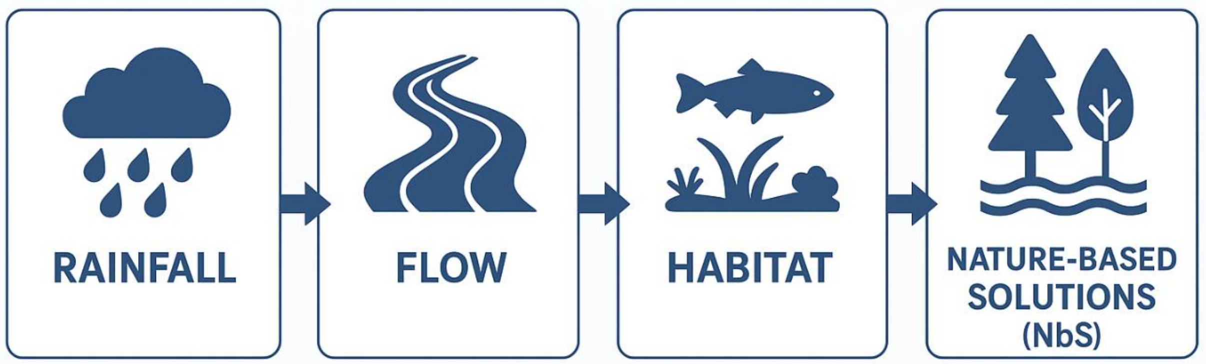

Figure 1: Infographic showing NbS project linkage to rainfall, flow and habitats

2 Catchment Description

The **Taumārere hydrological catchment** covers approximately **490 km²** and drains from the uplands of **Motatau Forest and the Hikurangi hills** (reaching 631 m NZVD) northeast toward the estuary and the **Bay of Islands** (Figure 2). The catchment is bordered by steep, volcanic landforms, and rolling hills, both native and commercial forested ridgelines, and characteristic lowland zones with alluvial valley floors and expansive remnant wetlands and agriculture.

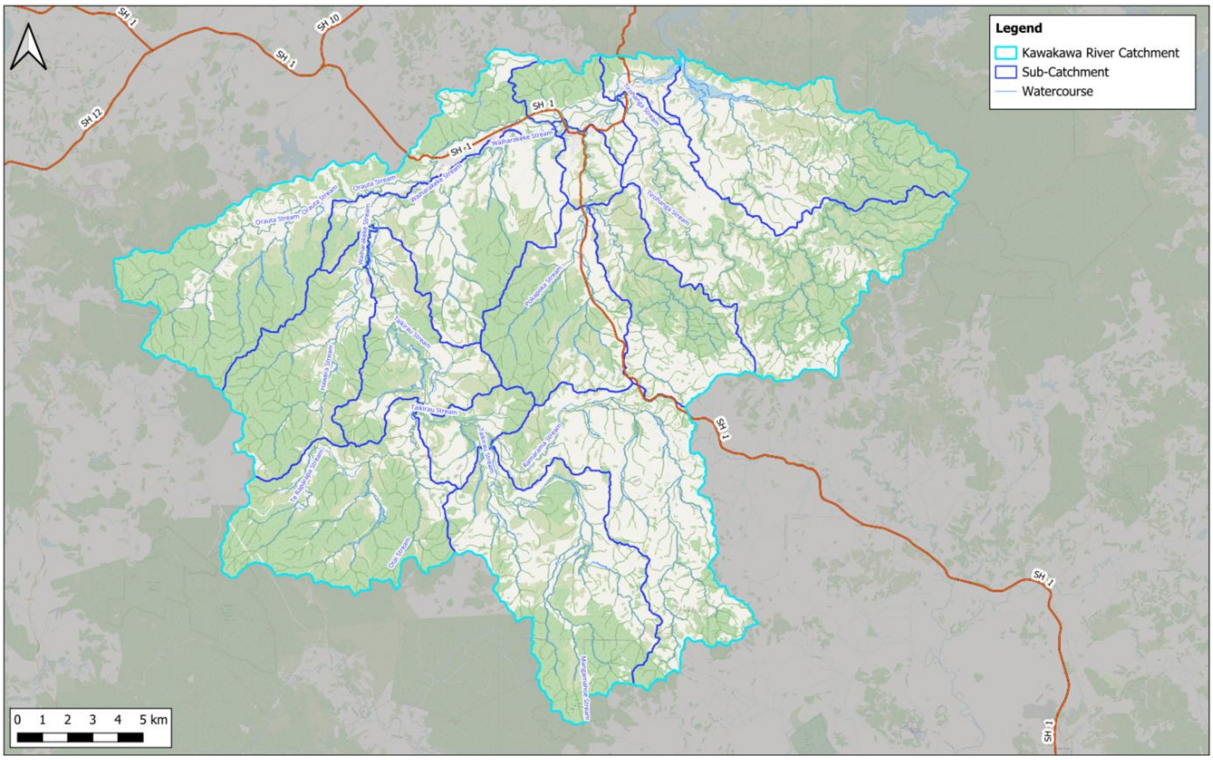

Figure 2: Catchment Hydrology

2.1 Climate and Rainfall

The catchment lies within a **humid subtropical zone**, with warm, humid summers and mild, wetter winters. Annual rainfall typically ranges from **1400 to over 2000 mm**, with **short-duration, high-intensity storms** common during summer. These events often occur after prolonged dry periods and drought, particularly under **El Niño conditions**, creating pulses of runoff that influence sediment and nutrient transport (NIWA, 2023).

2.2 Topography, Soils and Land Use

The landscape is a mosaic of **native and commercial forestry** in the upper hill country, transitioning to **pastoral agriculture** (livestock grazing) in mid- and lower-valley areas. Historically, the catchment was dominated by **wetlands and indigenous forests**, many of which have been cleared or drained for production. Remnant wetlands remain throughout the catchment in various states of condition, from near-natural systems to severely modified peat depressions or drained valley floors.

The main urban settlements include **Otiria**, **Moerewa**, and **Kawakawa**, with a total catchment population of around 5000. Due to the topography, many rural communities are located in low-lying areas or near watercourses, leaving them exposed to heightened flood hazard.

Geologically, the catchment includes a range of formations:

- Mudstones, sandstones, and mélange (mixed) units dominate the west and centre
- Peat deposits and soft alluvium are found in valley bottoms and wetland zones

- Greywacke, basalt, and limestone appear to the north and east, including the volcanic base beneath Moerewa

The catchment's **soils are highly variable**, with areas of **clay-rich, erosion-prone terrain** and low-permeability hill slopes interspersed with **peaty depressions**, **drained floodplain soils**, and smaller pockets of sandy deposits. Previous mapping has identified zones of **highly erodible** soils that are particularly sensitive to land disturbance and channel incision.

Land use includes:

- **Commercial forestry** (including post-harvest and replanted areas)
- **Stable and regenerating native forest and bush** in pockets and large expanses
- **High-producing pasture** in lowland and terrace zones
- **Marginal agricultural land** usually around other habitat margins (forest, wetland, rivers)
- **Drained floodplain paddocks** and remnant wetlands
- **Rural roading networks**, including unsealed roads and forestry access tracks

2.3 Hydrology and Waterways

The Taumārere catchment comprises a network of interconnected awa (rivers) and streams that drain from the steeper forested uplands, through repo (wetlands) and agricultural land toward the estuarine environment. Main watercourses include the Waiharakeke Stream, Ōtiria Stream, Kawakawa River, Keretu River, and Tirohanga Stream.

Downstream of Kawakawa township, these systems converge and become increasingly influenced by **tidal processes**. The Taumārere Estuary receives freshwater and sediment from across the catchment and serves as a mixing zone for freshwater and saltwater and provides important habitat for migratory fish and shellfish. Ngāti Hine recently identified layers of coastal shellfish shells along riverbanks adjacent to Kawakawa township.

Numerous natural **floodplain** and **wetland** areas are still present within the catchment in different conditions, from near natural to those disconnected by past drainage and modification. These areas attenuate peak flows by slowing the flow, improve infiltration and groundwater recharge, buffer water quality, and provide habitat.

2.3.1 Pressures on Waterways

Watercourses, and their **natural hydrological function** (flood attenuation, sediment transport, seasonal habitat quality), have been **modified** to varying degrees throughout the catchment, by:

- **Channel straightening** and historic stopbanking – leads to high energy flow and streambed "down-cutting" and infrequent floodplain activation.
- **Loss of riparian vegetation and in-stream wood** – increased temperatures, reduced habitat and food source for aquatic life.
- **Past dredging and deepening**, especially on floodplain reaches – lowers groundwater, degrades wetland and riparian habitat, passes forward flow downstream and can increase flooding in vulnerable locations.
- **Culverts and Infrastructure** (railways and roads etc) – these hard features can make **fish passage impossible,** alter hydrology and hydraulics (flow patterns), and act as point sources of pollutants (fine sediments or chemicals in runoff).
- **Stock access** - leads to erosion of banks, tramping aquatic habitats, and elevated nutrient and pathogen loading.

2.4 Water Quality Pressures

During consultation for this project local residents stated that they have **observed a decades-long decline in freshwater health**, marked by reduced tuna (eel) migration, declining species diversity, and visibly degraded water clarity. These observations align with water quality monitoring, which shows **elevated sediment, nutrient, and E. coli** concentrations—often exceeding ecological and recreational thresholds (NRC, 2016).

This degradation reflects land use and hydrological pressures across the catchment, including:

- **Sediment pulses following heavy rainfall**, which can block culverts, contribute to gravel bed smothering with silt, and obscure the natural role of hydro-ecological disturbance.
- **Nutrient-rich runoff and shallow groundwater pathways**, driven by intensive land use, legacy drainage, and riparian clearance.
- **Increased surface runoff**, resulting from land clearance, **soil compaction**, **overland flow**, and artificial **drainage ditch networks**.

The cumulative impact of these stressors is more evident during storm events and intense land use periods (forest harvest, ploughing) periods, when rainfall mobilises sediment and contaminants at scales that exceed the buffering capacity of aquatic systems.

3 Hydrological Inputs and Data Framework

This section outlines the datasets used and the logic underpinning the hydrological and water quality analysis for the Taumārere catchment. Rather than listing data sources in isolation, the assessment frames each dataset in terms of its role (cause and effect) in the **hydrological process chain**.

3.1 Hydrological Process Chain

The analysis follows the flow of energy and material through the catchment system — from rainfall to runoff, flood recession, sediment mobilisation, and water quality degradation. This structure shapes the rest of the analysis, ensuring clear links between input conditions, system response, and restoration strategy.

When considering the logical flow in a catchment (i.e., Cause → Effect → System Response), data can be thought of as in the table below:

Table 1: Components of the hydrological process chain

Hydrological Component	Role in the Chain	Description
Rainfall	Primary climatic input	Starts everything: drives timing, magnitude, and intensity of hydrological responses.
Flow	Hydrological response	Translates rainfall into streamflow, flood pulses, and baseflow patterns.
Flood Recession	Response dynamic – recovery phase	Describes how the river returns to normal (baseflow) — critical for habitat reset and refuge, and sediment settling.
Erosion-Triggering Events	Threshold trigger	High-intensity rainfall or flow events that initiate sediment mobilisation
Water Quality	Downstream outcomes	Cumulative effects of rainfall and flow – including sediment and E. coli levels.

3.2 Data Overview

Rainfall, river flow, and water quality data underpinning the analysis were sourced primarily from the **Northland Regional Council (NRC) Environmental Data Hub**[1], are shown in Figure 3, and include:

- **Rainfall gauges**: Ōtiria at Ngapipito, Waiharakeke at Okaroro Road, and Whakapara at Puhipuhi.
- **River flow/level gauges**: Waiharakeke at Willowbank, Ōtiria at Turntable Hill, Tirohanga at Below Old Mill.
- **Water quality stations**: Waiharakeke at Stringers Road, Waipapa at Forest Ranger (reference site).
- **Coastal flood hazard zones**: NRC for spatial mapping, Tonkin + Taylor Coastal Flood Hazard Assessment for Northland Region 2019-2020 report[2].

Publicly available hydrometric and water quality data were downloaded and processed in July 2025 to align with the **NZ Hydrological Calendar** between July 1st - June 30th.

[1] https://www.nrc.govt.nz/environment/environmental-data/environmental-data-hub/

[2] Tonkin + Taylor Coastal Flood Hazard Assessment for Northland Region 2019-2020 report Prepared for Northland Regional Council Prepared by Tonkin & Taylor Ltd Date March 2021 Job Number 1012360.1000.v4

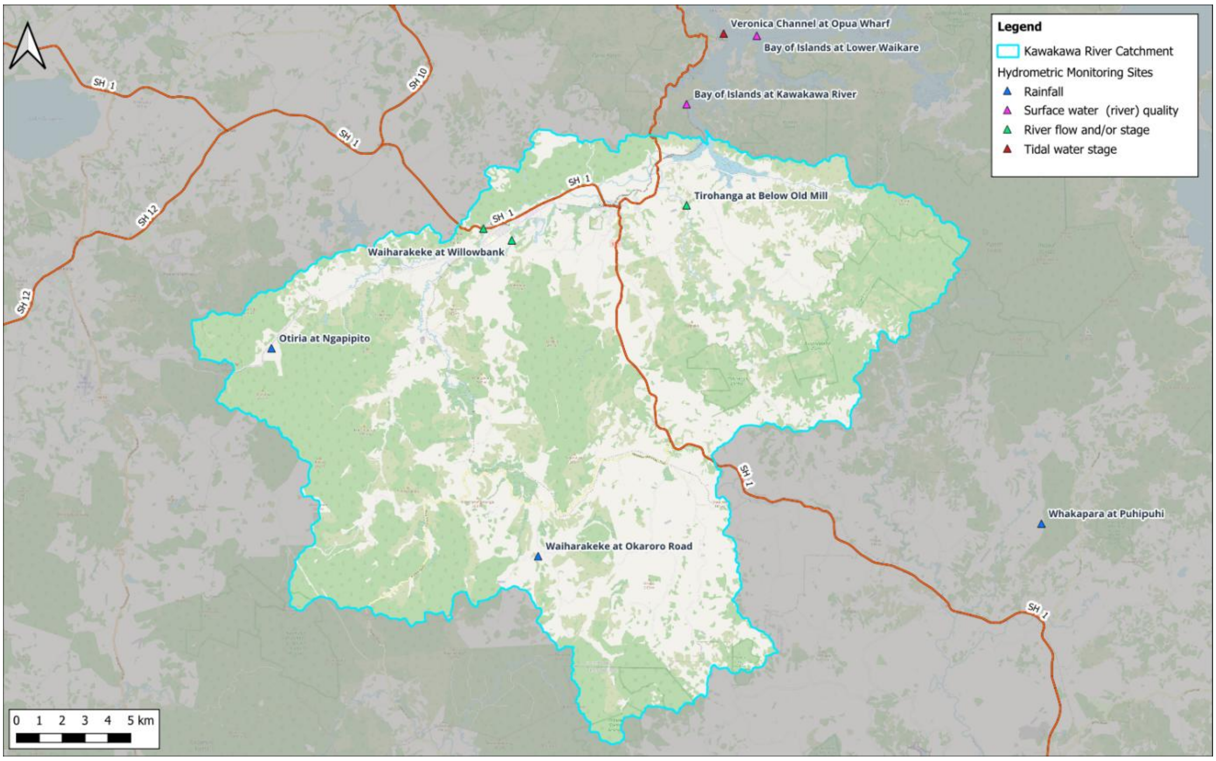

Figure 3: Locations of Monitoring Gauges

3.3 Data Gaps and Extrapolation

The monitoring network in the Taumārere catchment offers a valuable but uneven dataset for hydrological assessment. However, **limitations** include:

- **Patchy record lengths** at some rainfall and flow stations, reducing confidence in trend detection.
- **Spatial data gaps** in most headwater or forestry-dominated sub-catchments, particularly in steeper terrain (the upper catchment).
- **Localised storm events** may be underrepresented in the network due to high spatial variability in rainfall patterns, especially during summer convective storms.

4 Rainfall Patterns and Erosion Dynamics

Rainfall determines how rivers flow, sediment is mobilised, wetlands are recharged, and how dynamic habitats are in terms of disturbance. In a landscape of steep hills, compacted soils, and historical drainage modifications, the intensity and timing of rainfall events often dictates the severity of floods, erosion, and ecological disruption.

4.1 Historic Flood Events

This section draws on a recent article by RNZ titled ***"The Realities of Living in Northland's Most Flood-Prone Town"*** (RNZ, 2024a), which details how, over the past two decades, residents of Moerewa, Ōtiria, and the wider Taumārere catchment have faced multiple damaging flood events. These events are nothing new to Ngāti Hine and residents who have long lived alongside the swamps and floods. It should be noted that both the Otiria Spillway and Kawakawa deflection bank have recently been completed to provide flood relief.

Key flood events in the RNZ article include:

- **July 2007** – Severe flooding across Northland, including Moerewa and Kāeo, prompted then-Prime Minister Helen Clark to consider relocating flood-prone townships.
- **2011, 2014, 2018** – Recurring storms caused widespread disruption across Moerewa and Otiria, swamping culverts, flooding low-lying homes, and accelerating erosion in steep and cleared catchment areas.
- **July 2020** – A "one-in-500-year" rainfall event inundated the Ōtiria–Moerewa area, with floodwaters reaching the steps of Ōtiria Marae and prompting community-wide response and concern.
- **17 April 2025** – Ex-Cyclone Tam delivered extreme rainfall (up to 180 mm in a day) across Northland. Surface flooding (Figure 4), blocked access roads, and overwhelmed stormwater infrastructure again highlighted the system's vulnerability to flash floods following short-duration, high-intensity rainfall (RNZ, 2025a).

Figure 4: Drone image captured in the Taumārere catchment following Ex-Cyclone Tam

4.2 Rainfall Records

Analysis presented in this report was undertaken exclusively on the Whakapara at Puhipuhi rainfall gauge. Data was downloaded from the NRC Environmental Data Hub in July 2025. This gauge lies just outside the catchment; however, its long record (119 years) and comparable elevation and storm exposure make it a highly suitable index site for donor rainfall analysis. Catchment gauges with shorter records (e.g. Ōtiria) were used to validate the representativeness where needed. This validation confirmed a strong correlation in storm event timing and relative intensity, supporting the use of the Puhipuhi gauge as a reliable index for long-term pattern analysis.

4.3 Long-Term Rainfall Patterns

Understanding long-term rainfall patterns helps identify shifts in climate behaviour that affect flood risk, baseflows, and ecosystem function. While seasonal rainfall can fluctuate widely, persistent patterns over time reveal deeper climatic signals.

Figure 5 shows the long-term Puhipuhi gauge daily rainfall totals expressed as a percentage of the long-term average annual rainfall (2013 mm). A 10-year rolling average (black line) highlights decadal trends with blue = wetter-than-average years and red = drier-than-average years.

Key observations:

- The last two decades show **fewer clustered wet years** and more **consistent deficits**.
- The rolling average has mostly stayed below 100% since 1998, signalling a shift toward a **drier or more variable climate**.

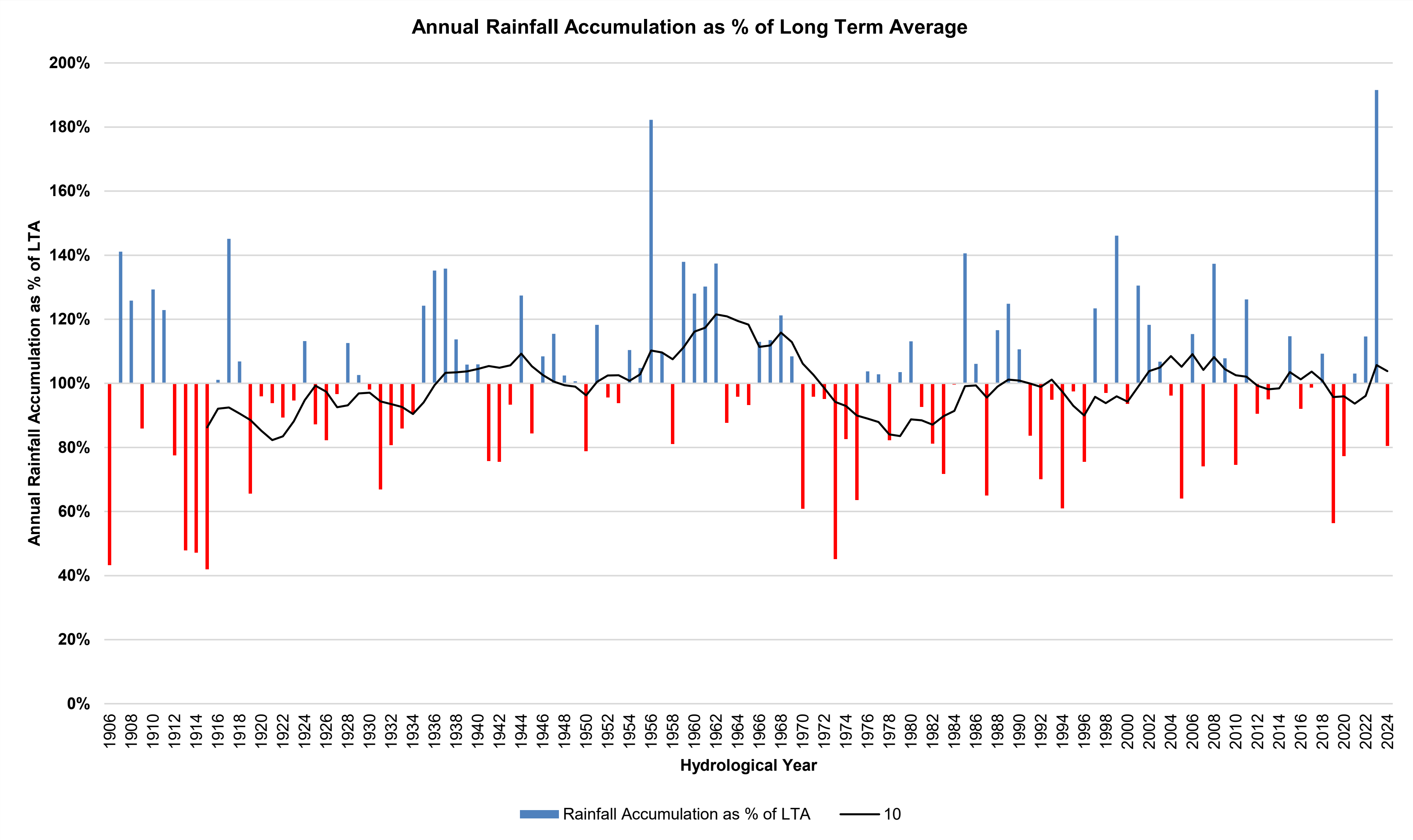

Figure 5: Annual Rainfall Accumulation as % of Long-Term Average

4.3.1 El Niño Southern Oscillation (ENSO) Index

Figure 6 compares monthly rainfall totals at the Puhipuhi rain gauge with the El Niño Southern Oscillation (ENSO) Index to explore climatic influence on long-term rainfall patterns (NOAA, 2025). ENSO is a major driver of interannual variability in Aotearoa's climate, with **El Niño phases** typically associated with **drier-than-average conditions** in Northland due to increased westerly flows, and **La Niña phases** linked to **wetter conditions**, often driven by moist easterlies and tropical influence. The red line shows monthly ENSO values (averaged over a three-month rolling window), while the blue columns show the monthly rainfall totals. To help visualise broader hydrological shifts, a **12-month moving average** of rainfall (light blue line) is overlaid.

Due to the use of rolling ENSO indices and smoothed rainfall trends, there is a **natural lag** between ENSO peaks and rainfall responses in the chart. Typically, **La Niña events lead to elevated rainfall totals 1–3 months later**, while **El Niño peaks often precede declines in rainfall** within a similar window. These lagged effects are apparent across the time series, especially during sustained ENSO phases such as the **1997–98 El Niño** and the **2010–12 La Niña**, which correspond with clear shifts in rainfall patterns.

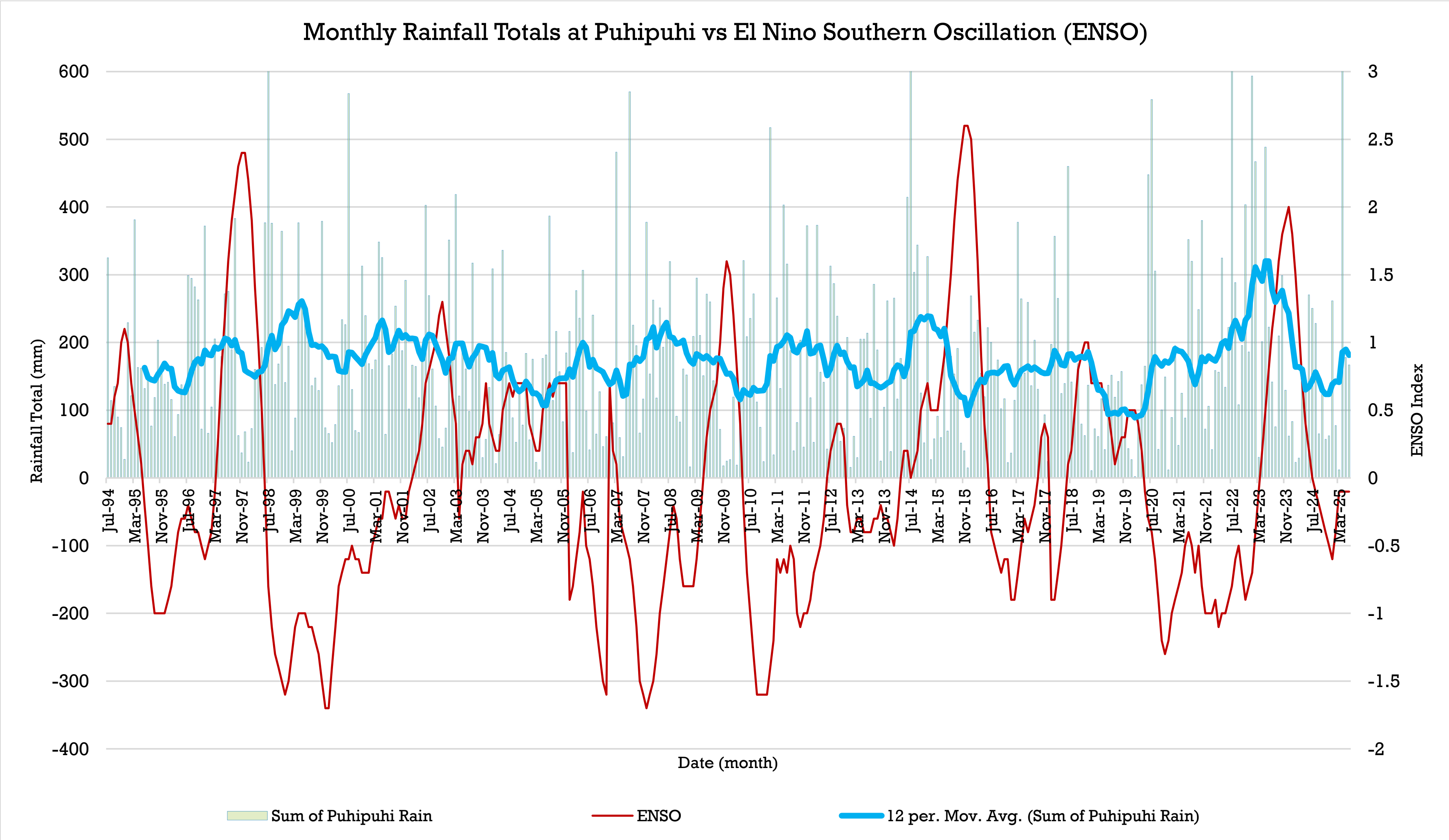

Figure 6: Monthly Rainfall Totals vs El Niño Southern Oscillations

4.3.2 30-year Seasonal Rainfall Trends

Error! Reference source not found. and Table 2 show that over the past 30 years, **seasonal rainfall patterns** at the Puhipuhi gauge have changed against the 30-year yearly and seasonal averages. The patterns and trend observations are shown in Figure 7 and Table 2. The main seasonal trends by quarter are as follows:

Q1 – July to September (Winter)

- Wettest and most reliable quarter, averaging 643 mm.
- Typically delivers strong frontal rainfall and low-pressure systems, making it a primary recharge period for aquifers, wetlands, and pasture.
- July often includes large rainfall totals and can be the wettest month of the year.
- September becoming increasingly wet over the last decade.
- For farmers, these years can limit paddock access, cause pugging, and delay pasture recovery despite high rainfall totals.
- For eel kaitiaki, high Q1 flow events may help upstream migrations.

Q2 – October to December (Spring)

- In record it is the driest quarter (avg. 388 mm), but the last 5 years have seen higher rainfall in October and November.
- Lack of Q2 recharge may:
  - Delay or limit spring pasture production, leaving soils dry heading into summer.
  - Suppress early flow cues for downstream tuna migration or spawning movement.
  - Catchment systems are more vulnerable when both Q2 and Q3 are dry — with increased pressure on baseflows, crop irrigation, and early summer stock water supply.

Q3 – January to March (Summer)

- Second driest season in the long record with an average of 488 mm per year.
- This period is increasingly shown as being volatile with wide swings from wet years like 2022 (1091 mm) to near record lows in 2023 (136 mm), and 2024 (351 mm).
- 2023–2024 had consecutive extremely dry Q3 periods, suggesting a structural shift toward harsher dry summers.
- Possible ecological effects:
  - Streamflows collapse without sufficient groundwater buffering.
  - Wetland water levels fall sharply.
  - Migration, spawning, and larval survival windows for tuna and inanga are restricted.
- For farmers: drought resilience is now a yearly concern, with early destocking and crop failure risks peaking in Q3.
- Flood risk paradox: Despite low rainfall totals, dry soils and hardened pastures can create higher runoff rates during summer storms.

Q4 – April to June (Autumn)

- Averages 601 mm and historically acted as the "recovery" or balance quarter topping up catchments after dry Q2/Q3, especially May.

- In wet years Q4 helps lift annual rainfall totals, replenish baseflows, and initiate wetland recharge.
- Since 2010, April and May show increasing low rainfall months, however, exceptions remain.
- Drought years like 2018 had poor Q4 totals, compounding dry conditions from prior quarters and delaying the start of the wet season.
- For tuna and aquatic species, Q4 can be a last-chance window for downstream migration or spawning before winter conditions begin.
- Management note: Timing restoration or buffering work in Q4 zones may help prepare for next winter’s rainfall and intercept surface runoff early.

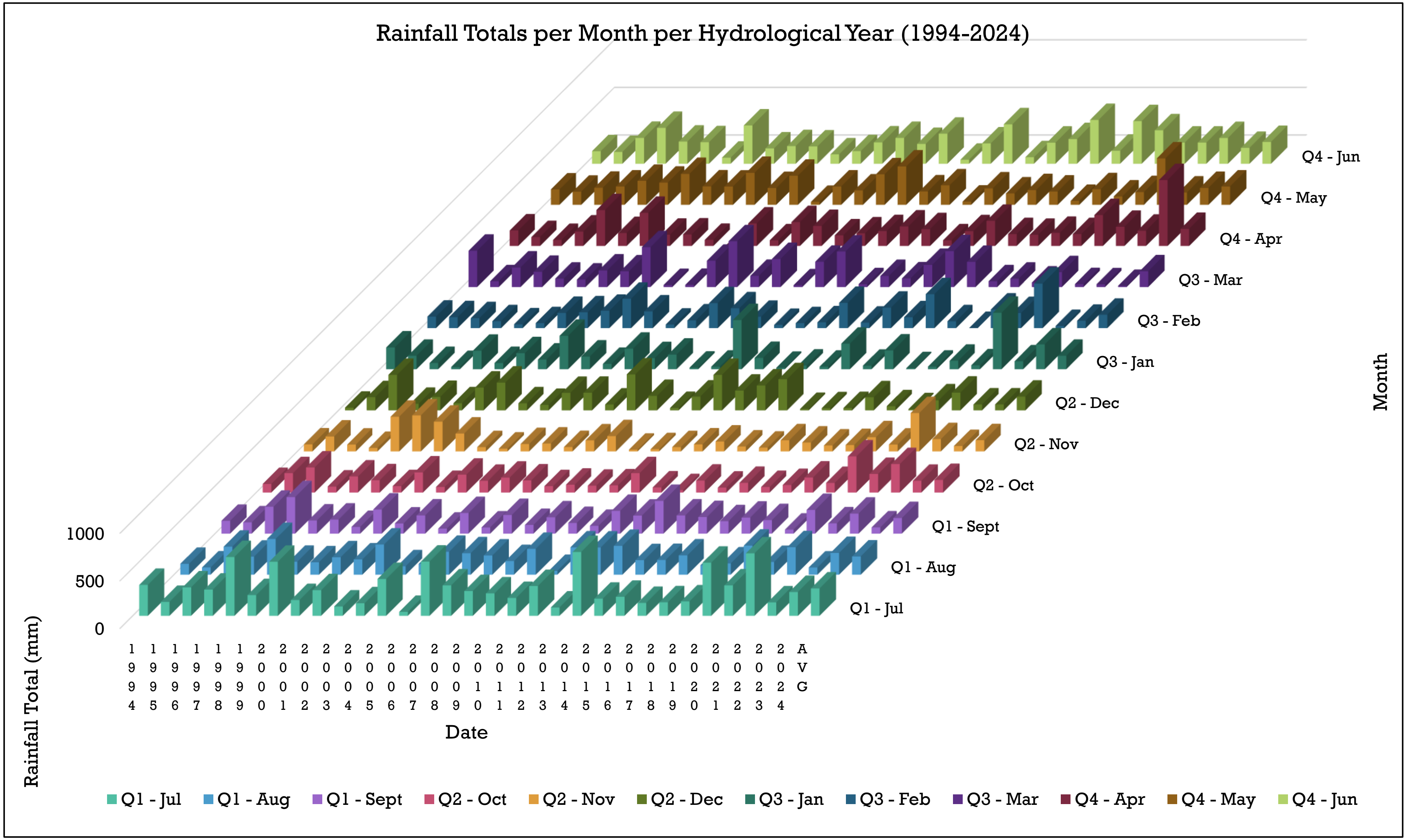

Figure 7: Rainfall Totals per Month per Hydrological Year (1994-2024)

Table 2: Seasonal Wet and Dry Hydrological Years against 30-year Average Rainfall

Hydro Year	Q1 - Jul - Sept	Q2 - Oct - Dec	Q3 - Jan - Mar	Q4 - Apr - Jun	Total Annual Rainfall (mm)
1994	574	2	732	457	1766
1995	342	499	319	356	1516
1996	876	707	376	515	2474
1997	848	168	257	721	1994
1998	1132	674	323	862	2992
1999	502	582	197	596	1877
2000	768	619	504	738	2629
2001	603	691	433	715	2442
2002	536	178	953	474	2141
2003	607	275	464	586	1930
2004	274	386	255	370	1284
2005	718	425	531	642	2315
2006	347	235	680	224	1485
2007	991	561	534	669	2754
2008	613	396	521	633	2162
2009	575	115	166	641	1496
2010	620	244	818	851	2532
2011	310	622	544	340	1816
2012	839	335	107	624	1905
2013	563	391	421	626	2001
2014	1318	505	176	302	2301
2015	524	107	717	497	1845
2016	529	242	529	679	1979
2017	470	176	820	725	2190
2018	410	279	145	296	1130
2019	413	268	118	751	1550
2020	907	262	333	566	2066
2021	703	558	357	681	2298
2022	1053	785	1091	913	3842
2023	427	490	136	560	1613
2024	544	243	351	1038	2175
Average	643	388	448	601	2081

WET	NORMAL	DRY

4.4 Rainfall Event Analysis

Rainfall can trigger environmental and hydrological response, and this section looks at the frequency and magnitude of these events through the lens of flooding and water quality (sediment). It is more common to look at high intensity rainfall events, like the +25 mm/hr events to track large sediment inputs (Marsden, 2023), however, it should also be noted that in Northland, unsealed gravel roads also contribute to the sediment load, particularly during short-duration, high-intensity rain i.e., +10 mm/hr.

Observations suggest that even 5-10 minutes of heavy rain can mobilise loose fines and road-edge sediment which is often routed directly to waterways via roadside drains and culverts. Despite this, road networks are often overlooked in landscape NbS restoration in favour of large-scale erosion estimates based on slope and land cover.

The hourly rainfall data at Puhipuhi gauge have been analysed for the following rainfall thresholds:

- **Low-intensity rainfall (>10mm/hr)** – Drives mobilisation from exposed soils and access tracks or unsealed roads, especially on slopes.
- **Moderate-intensity rainfall (>25mm/hr)** - Drives rapid runoff, flash flooding and erosion in steep sub-catchments and triggers overland flow in compacted or drained lowlands.
- **High-intensity rainfall (>50mm/hr)** - Drives rapid runoff, flash flooding and erosion in steep sub-catchments and triggers overland flow in compacted or drained lowlands. Can overwhelm local drainage infrastructure. Intense rainfall often results in higher more disruptive river flows resulting in instream erosion and sediment transport.
- **3-day Cumulative Rainfall Total (mm)** - Prolonged rainfall over several days saturates the catchment, reduces infiltration capacity, increases flashiness and flood risk even from modest storms. Long periods of saturated ground can increase the likelihood of slips and slumps occurring.

4.4.1 Rainfall Event Threshold Results

The following tables provide the total hours counted in the condition assessed i.e., Table 3 provides the monthly total numbers of hours per year spent above the low intensity threshold of 10 mm/hr.

The tabulated results show that:

Low-intensity rainfall (>10mm/hr)

Table 3 reveals strong variability both within and between years, with occasional high-frequency clusters of these low-intensity but persistent rainfall events. These events appear scattered across all seasons, though winter and early spring (Jul–Sep) feature more frequent prolonged spells. This pattern suggests consistent pressure of silty runoff, especially where land is disturbed or compacted, even outside major storm events. It highlights the need for all-season erosion controls on exposed soil surfaces, not just during high-intensity storms, and controlling runoff at source.

Moderate-intensity rainfall (>25mm/hr)

Table 4 shows high-intensity events generally cluster between Dec-April, however, they can occur in any month. While they don't always occur every year, their impacts can be disproportionately large by triggering slips, damaging infrastructure, and overwhelming riparian buffers. This underlines the need for targeted resilience planning, especially around erosion-prone slopes, culverts, and vulnerable stream margins.

High-intensity rainfall (>50mm/hr) (table not provided)– Events of this intensity rainfall are rare in the 30-year records having only occurred on 5 occasions in March 1994 and 1996, April 1998, and July 2020. While these high-intensity events are rare in the record, their potential to cause disproportionate geomorphic change, such as slips and channel erosion, is high. Event-specific analysis would be required to quantify their historical impact.

3-day Cumulative Rainfall Total (mm) –

Table 5 shows that these periods tend to occur across multiple seasons, though they cluster more in April – July. Notably high cumulative totals were recorded in 1998, 2000, 2007, and 2022, indicating seasons with sustained rainfall that could trigger slope failures, overland flow, and prolonged wet soil conditions. The visual spread shows that these risks are not isolated to extreme storm years but can occur through persistent wet weeks.

Table 3: Hours count per month over 10 mm/hr

Hydro Year	Q1 - Jul	Q1 - Aug	Q1 - Sept	Q2 - Oct	Q2 - Nov	Q2 - Dec	Q3 - Jan	Q3 - Feb	Q3 - Mar	Q4 - Apr	Q4 - May	Q4 - Jun
1994	9	1	0	1	0	0	4	1	10	1	2	2
1995	1	0	2	1	2	2	0	1	1	3	2	1
1996	3	7	6	0	0	9	0	1	3	1	2	15
1997	1	1	0	0	0	0	0	2	3	0	4	4
1998	12	4	1	3	7	3	2	0	1	13	1	5
1999	6	0	2	2	9	0	0	0	1	1	5	1
2000	3	2	1	1	5	6	4	1	1	9	7	0
2001	3	2	5	3	5	3	0	2	1	0	4	5
2002	3	3	2	1	0	1	8	4	4	1	3	3
2003	0	1	1	0	0	1	4	7	0	0	6	1
2004	1	0	0	0	0	1	1	0	0	0	0	1
2005	7	1	3	1	0	6	5	0	7	7	7	2
2006	0	4	0	1	0	0	1	1	15	0	1	1
2007	15	6	0	0	1	2	3	6	0	5	2	2
2008	10	2	0	0	2	0	0	7	9	1	1	1
2009	5	1	3	0	0	0	1	2	0	3	0	0
2010	4	1	1	0	0	1	15	0	2	4	11	7
2011	1	0	2	0	0	6	0	0	12	0	1	0
2012	4	4	4	0	0	3	0	0	0	5	3	1
2013	0	1	2	0	0	4	0	1	2	7	0	16
2014	17	13	1	2	1	6	0	0	0	2	0	0
2015	2	2	2	0	0	0	3	1	7	3	3	3
2016	0	0	3	1	2	0	0	1	12	4	1	2
2017	0	0	0	0	0	0	3	12	3	5	3	12
2018	4	0	0	2	0	3	0	0	0	1	0	0
2019	0	1	0	5	0	0	0	0	0	3	1	5
2020	17	3	0	1	6	0	2	7	0	4	1	5
2021	2	2	4	1	0	1	0	2	3	10	3	4
2022	20	0	1	3	12	1	7	10	0	7	4	5
2023	2	0	3	6	1	0	1	0	0	3	2	5
2024	1	3	0	2	0	1	7	0	0	12	3	2

Table 4: Hours count per month over 25mm/hr

Hydro Year	Q1 - Jul	Q1 - Aug	Q1 - Sept	Q2 - Oct	Q2 - Nov	Q2 - Dec	Q3 - Jan	Q3 - Feb	Q3 - Mar	Q4 - Apr	Q4 - May	Q4 - Jun
1994	0	0	0	0	0	0	2	0	3	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	1	0	0	3	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	1	0	0	0	0	0	0	0	0	4	0	0
1999	0	0	1	0	0	0	0	0	0	0	0	0
2000	1	0	0	0	0	1	0	0	0	0	0	0
2001	0	0	1	0	0	0	0	0	1	0	0	0
2002	0	0	0	0	0	0	0	0	1	0	0	0
2003	0	0	0	0	0	0	1	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	1	0	0	0	0	1	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	5	0	0	0
2007	1	0	0	0	0	0	0	0	0	1	0	0
2008	0	0	0	0	0	0	0	2	1	0	0	0
2009	0	0	0	0	0	0	0	0	0	1	0	0
2010	0	0	0	0	0	0	5	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	2	0	0	0
2012	0	2	1	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	1	0	0	0	0	0	1
2014	0	1	0	0	0	0	0	0	0	0	0	0
2015	0	1	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	2	0	0	0
2017	0	0	0	0	0	0	0	1	0	0	0	0
2018	0	0	0	0	0	1	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	2	0	0
2020	3	0	0	0	0	0	1	1	0	0	0	2
2021	0	0	0	0	0	0	0	0	1	0	0	0
2022	0	0	0	0	1	0	1	0	0	1	0	0
2023	0	0	0	0	0	0	0	0	0	0	0	0
2024	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Hours Count per month of greater than 75mm of cumulative rainfall (wet catchment)

Hydro Year	Q1 - Jul	Q1 - Aug	Q1 - Sept	Q2 - Oct	Q2 - Nov	Q2 - Dec	Q3 - Jan	Q3 - Feb	Q3 - Mar	Q4 - Apr	Q4 - May	Q4 - Jun
1994	131	0	0	0	0	0	91	0	58	23	52	0
1995	0	0	0	66	68	51	22	0	0	0	43	0
1996	94	75	75	96	0	55	30	0	72	0	67	86
1997	63	57	100	0	0	0	0	0	9	50	64	83
1998	275	193	0	38	98	63	20	0	0	139	62	65
1999	73	0	68	61	103	0	0	0	41	0	72	62
2000	290	0	0	0	84	69	74	0	0	147	141	0
2001	0	0	72	57	58	89	0	26	57	1	30	116
2002	69	55	0	0	0	0	92	81	150	0	36	0
2003	0	38	0	32	0	0	37	91	40	0	81	0
2004	0	0	0	0	0	37	20	51	0	0	0	30
2005	95	0	63	0	0	72	75	0	82	69	144	0
2006	0	76	0	0	0	0	30	0	75	15	0	0
2007	176	71	66	0	0	145	67	81	0	75	86	64
2008	119	79	0	0	56	0	0	24	126	89	57	71
2009	74	0	0	0	0	0	0	61	0	15	76	0
2010	67	71	0	0	0	47	152	0	65	0	151	137
2011	52	0	0	15	0	105	33	0	79	52	0	0
2012	73	52	89	0	0	72	0	0	0	73	0	41
2013	0	71	0	0	0	144	0	121	65	73	0	92
2014	188	98	57	0	0	141	0	0	0	0	0	0
2015	0	0	0	0	0	0	73	66	92	65	0	2
2016	37	0	0	0	0	0	0	0	156	124	22	125
2017	0	48	0	0	0	0	0	155	64	62	59	160
2018	68	0	60	0	0	46	0	0	0	23	0	0
2019	16	0	42	69	0	0	0	0	0	69	7	153
2020	126	69	0	0	69	0	0	72	0	0	0	139
2021	68	0	73	95	0	0	0	68	71	96	40	21
2022	291	80	0	65	133	55	276	141	0	12	252	54
2023	0	0	17	51	42	0	0	0	0	66	0	9
2024	57	73	0	0	0	0	77	0	0	262	33	0

5 Flow Analysis

This section explores long-term, seasonal and event flow behaviour to assess hydrological response and resilience to rainfall-driven conditions. Three core analyses presented are:

- **Seasonal Long-term Trends**: This section builds on the seasonal rainfall analysis to look at long-term statistics and trends in flow.
- **Seasonal FRE3:** FRE3 events are broken down by month and hydrological season to evaluate shifts in timing and seasonal flow cues - critical for fish migration, sediment flushing, and wetland connection.
- **Event Dynamics:** Selected flow events are analysed in detail, with a focus on flood recession—the duration and shape of post-peak flow decline—which influences soil saturation, channel erosion, and ecological recovery.

Flow analysis has been undertaken on the **Waiharekeke Stream** flow and level gauge with data available from 1967; however, only the last 30 years have been assessed as over 560 days of data are missing including 22 days over the last 30 years. Missing daily data values over the last 30 years could be infilled manually by averaging the hourly data record.

5.1 Seasonal Long-Term Trends

Seasonal flow patterns in the catchment reveal strong contrasts, shaped by rainfall seasonality, land use, and catchment responsiveness. These patterns highlight the need to consider **shifting seasonal baselines** when planning NbS interventions and ecological restoration.

Over the last 30 years, general observations from the analysis and data statistics shown in Table 6 suggest the seasonal trends are:

- **Q1 (Jul–Sep)** delivers the **highest and most consistent flows**, reflecting saturated soils and winter rain bands — critical for sediment transport and flood peak buffering.
- **Q2 (Oct–Dec)** is consistently dry with **lower flows**, often marking the onset of water stress and reduced recharge heading into summer.
- **Q3 (Jan–Mar)** exhibits the **lowest baseflows** overall, but occasionally features short, sharp peaks from convective storms — a **flashy dry season** with ecological consequences.
- **Q4 (Apr–Jun)** was historically a transitional period with important ecological cues, but appears to be **weakening in recent years**, delaying or reducing connectivity for species such as longfin eel (tuna).

Table 6: 30-year Seasonal Flow Statistics at the Waiharekeke Gauge

Season	Q1 - Jul - Sept	Q2 - Oct - Dec	Q3 - Jan - Mar	Q4 - Apr - Jun
Minimum	0.696	0.049	0.007	0.008
Maximum	219.26	68.059	198.993	141.252
Mean	9.566	2.848	2.812	6.286
Median	5.317	1.184	0.508	2.616
95 percentile	31.948	11.91	12.588	26.064
75 percentile	10.73	2.551	1.5	7.252
25 percentile	2.932	0.603	0.159	0.766
5 percentile	1.432	0.188	0.042	0.095

5.2 Seasonal FRE3

Frequency of Floods Exceeding three times the median flow (Q50) flow event are called FRE3 events or “freshes”. They are short-lived but high-energy flow events that provide essential **flushing, sediment movement, and ecological reset functions**. For instance, tuna (longfin eel), these flows can act as **migration cues**, often aligning with seasonal triggers in late summer and autumn.

By counting FRE3 events per season across the 30-year dataset as shown in visually in Figure 8 and tabulated in the Appendix, several patterns emerge:

- **Q1 (Jul–Sep)** shows that since around **2010**, FRE3 events occur more in September than previously i.e., Q1 is now wetter. Pre-2010, Jul – Sep had an average of 12.8 FRE3 events per month, post-2010, it averages around 15.5 per month; a **18% observed increase in FRE3 events**.
- **Q2 (Oct–Dec)** pre-2010, October and November were drier months with an average 2.75 FRE3 events per month. Post -2010, it has risen to 3.62; a **24% observed increase in FRE3 events**.
- **Q2 (Oct–Dec)** Post -2010 there is increasing variability in the number of FRE3 events, i.e., 2020 had 0, whilst 2021 (a wet year) had 24 in October.
- **Q2 (Oct–Dec)** has historically had large, isolated summer storms.
- **Q3 (Jan–Mar)** exhibits highly **variable FRE3 behaviour** — sometimes dry, sometimes prone to back-to-back wet years. There is
- **Q4 (Apr–Jun)** shows historically reliable FRE3 activity, but in recent years events have been **less frequent or delayed to June**, reducing water resources and possibly weakening downstream migration triggers for Tuna.

5.2.1 Inferred Implications for Tuna

FRE3 flows are critical for triggering downstream migration of **tuna**. These elevated flows help reconnect fragmented habitats, increase river velocities, and cue movement toward the coast. Historically, **FRE3 events in April to June** aligned with seasonal migration windows for mature tuna.

However, **FRE3 seasonal analysis shows a decline in late autumn events**, with flows now more commonly peaking in **June-September**. This shift may delay or disrupt migration cues, especially for longfin eels which are highly sensitive to flow timing. The loss of these earlier flow triggers could reduce spawning success and contribute to long-term population pressures.

While this study does not attempt a full ecohydrological assessment, the pattern suggests a potential **mismatch between flow signals and ecological need**, reinforcing the value of restoring seasonal flow variability in catchment planning.

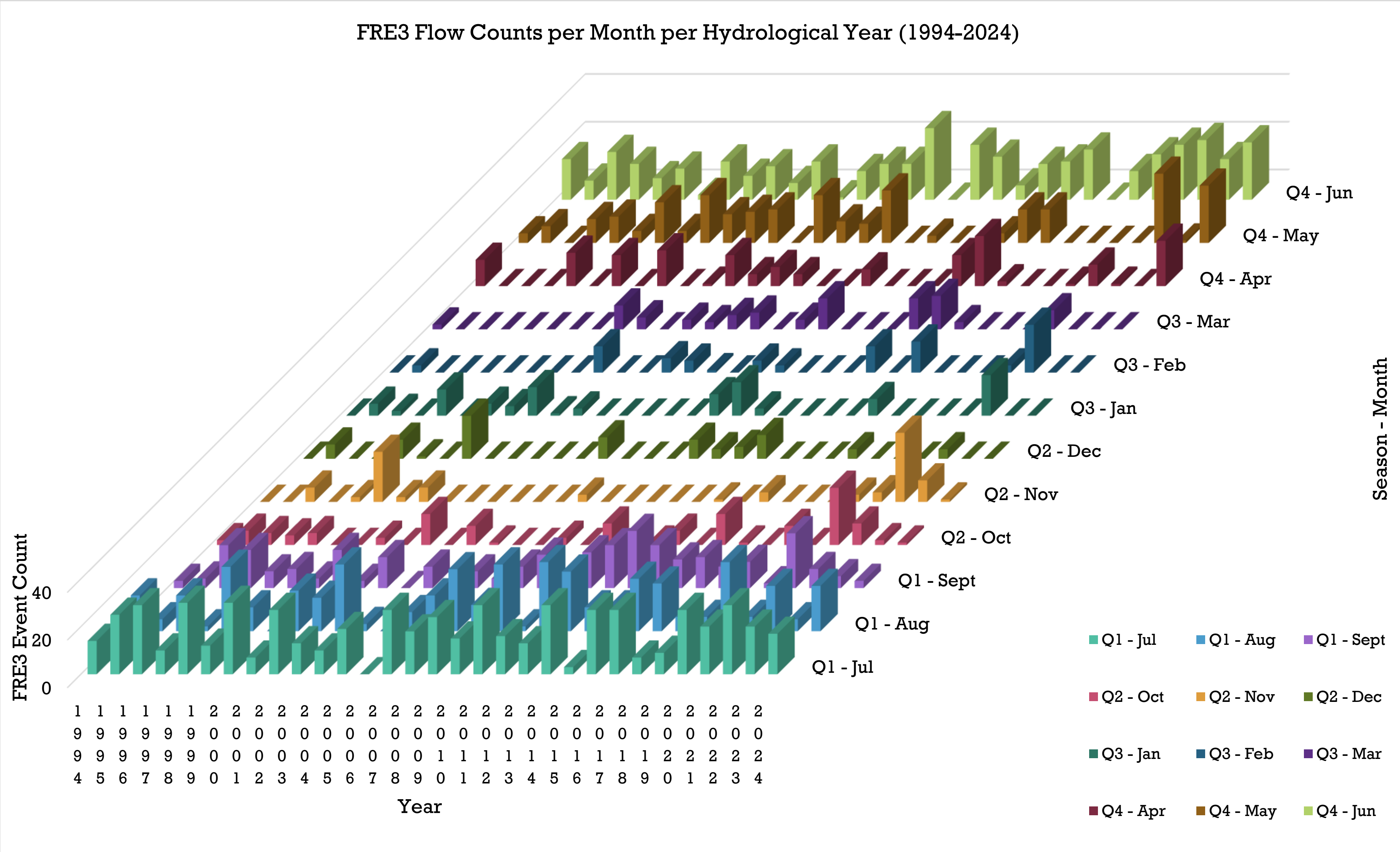

Figure 8: FRE3 Flow Counts per Month per Hydrological Year (1994-2024)

5.3 Interpreting Flow Response – hourly data match to flood events

Once rainfall lands in the Taumārere catchment, the speed and shape of the resulting river response - known as the **hydrograph** — provides insight into landscape behaviour, storage capacity, and flood risk. By examining peaks, recessions, and seasonal variability, this section connects meteorological inputs to real-world hydrological consequences.

5.3.1 Flood Recession

Following a flood, water levels recede and the "flood recession" pattern provides an insight into the hydrological regime. The duration and stability of post-flood conditions are critical for key freshwater species reliant on consistent habitat during migration, spawning, or juvenile development stages.

The following example flood events were those captured in the RNZ news article "***The Realities of Living in Northland's Most Flood-Prone Town***" (RNZ, 2024a) and show the nature of th tailwaters in flood events in the catchment.

Figure 9 shows the rainfall and flow response for the **July 2007** flood which was driven by up to 37.5 mm/hr of rainfall translating to a peak flow of over 152 m^3/s on 11th July at 18:00. The preceding days saw several smaller rainfall events that would have wet the catchment up. The days following the peak saw a typical seasonal downpour. The flood recession to pre-storm baseflow of approx. 4.5 m^3/s occurred on 28th July at 13:00 was around 400 hours, or almost 17 days.

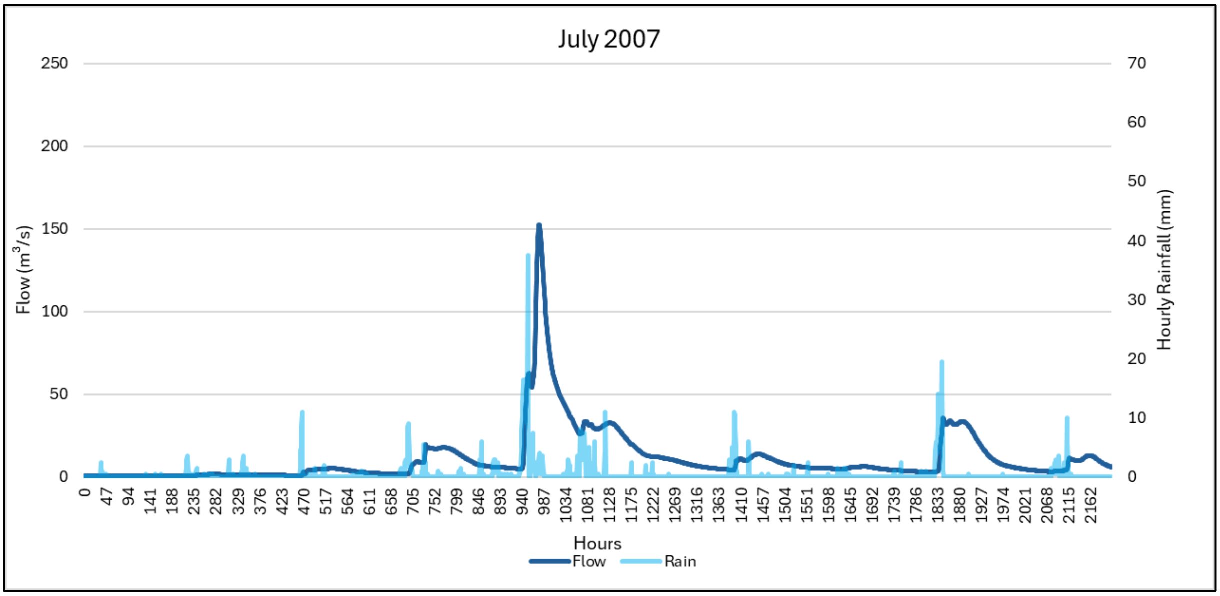

Figure 9: Event 1: July 2007 Rainfall and Flow Response

The July 2020 flood was described as a **1 in 500 year event** with up to 66.8 mm/hr of rainfall translating to a peak flow of over 200 m^3/s on 18th July at 18:30 (Figure 10). The preceding days saw one large downpour over several hours that would have wet the catchment up and filled vital storage, and little rain the days immediately following the storm. The flood recession to pre-storm baseflow of approx. 5 m^3/s occurred on 31st August at 18:30 was around 312 hours, or 13 days.

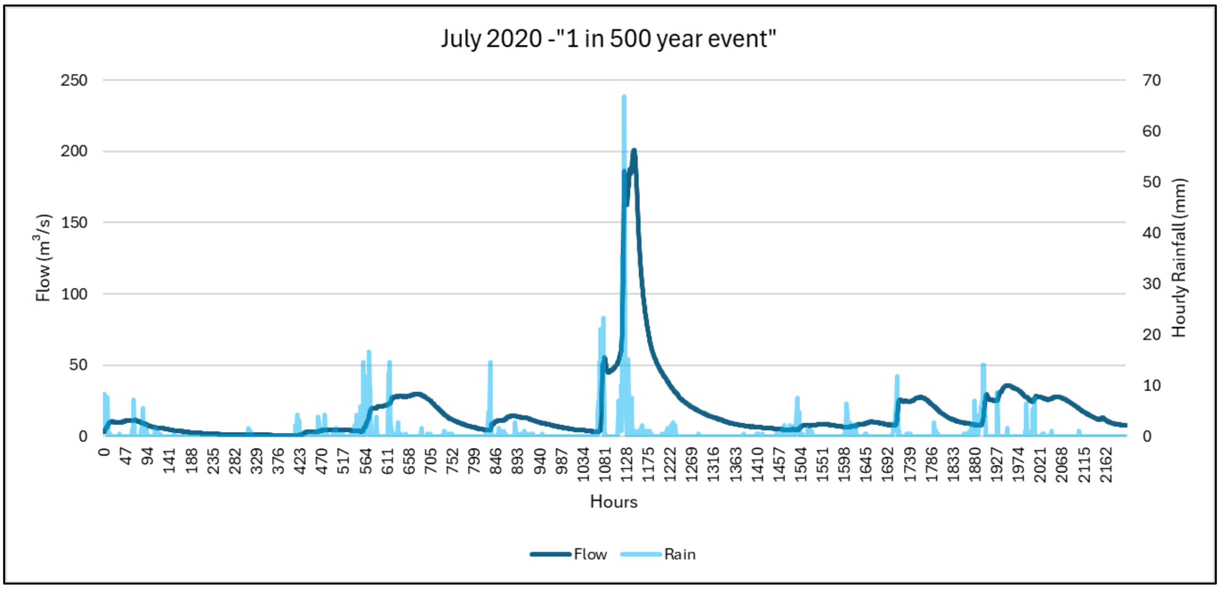

Figure 10: Event 2: July 2020 Rainfall and Flow Response

Cyclone Gabrielle in February 2023 did not cause the widespread destruction to the Northland that it did to elsewhere in Aotearoa (Figure 11). The event had up to 47.2 mm/hr of rainfall translating to a peak flow of over 167 m³/s on 14th February at 19:30. Several days before the cyclone saw a short, wet period that would have wet the catchment up and filled vital storage. There was little rain the days immediately following the storm. The flood recession to pre-storm baseflow of approx. 3.7 m³/s occurred on 26th February at 16:30 was around 285 hours, or 12 days.

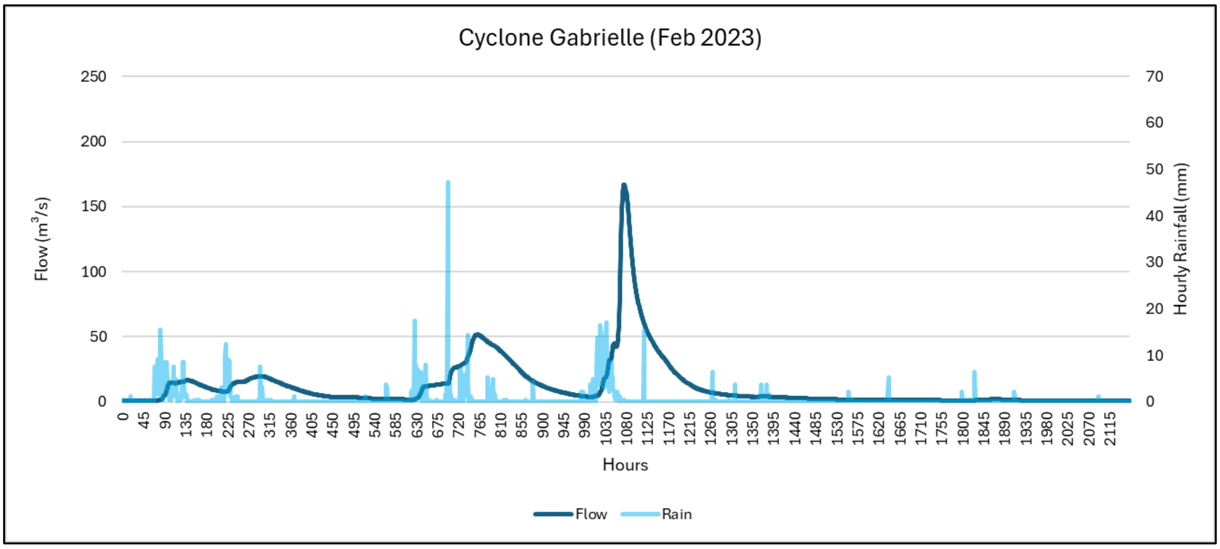

Figure 11: Event 3: Cyclone Gabrielle - Feb 2023 Rainfall and Flow Response

Figure 12 shows the rainfall and flow response for **Ex-cyclone Tam** which fortunately passed the Northland with relatively little damage than other locations further south in the country. The peak river flow of just over 64 m³/s occurred on 30th April at 19:30 following peak rains of just 23 mm/hr. A solid block of rain in the preceding days left river flow still at over 10 m³/s and flood storage within the catchment was likely at capacity. The combination of a wet catchment and sustained periods of moderate rainfall can result in a quick "flashy" response to the rain i.e., water levels in rivers can jump up quickly following rain.

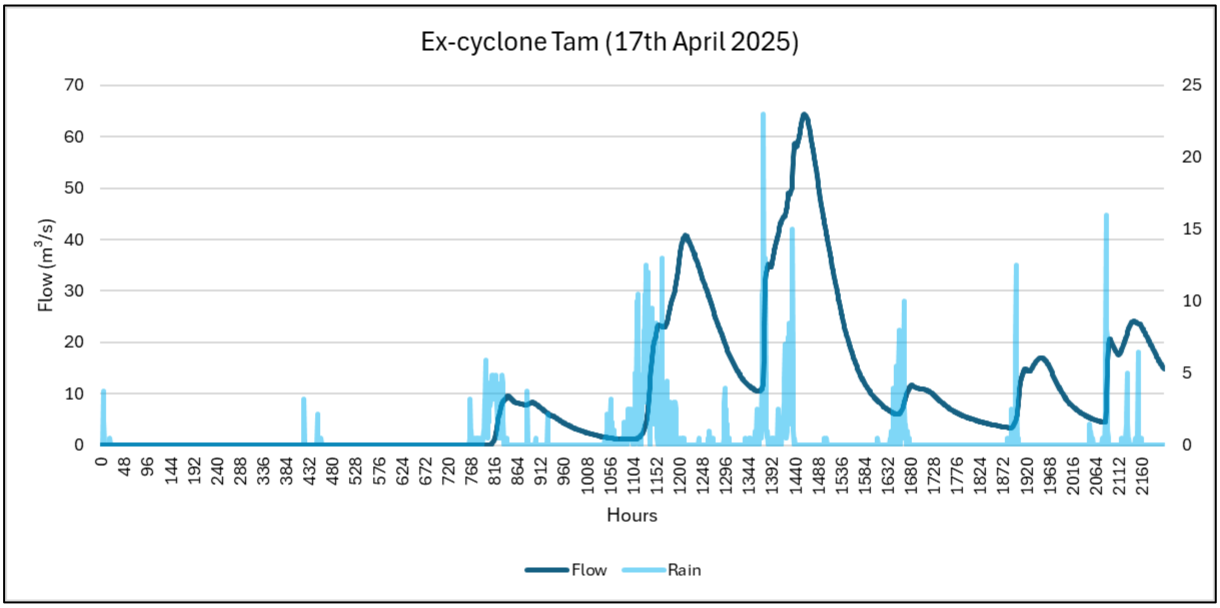

Figure 12: Ex-Cyclone Tam - April 2025 Rainfall and Flow Response

5.3.2 Flashy Peaks and Lag Times

The hourly data was further assessed to suggest that the Taumārere system displays relatively **short lag times** between rainfall and peak flow. This results in a **"flashy" flow regime**, where storm runoff translates into sharp, high hydrograph peaks with little attenuation (storage). These characteristics are typical of modified Northland headwater catchments with high runoff and limited water storage capacity.

The Waiharekeke gauge is in the lower reaches of the catchment. The degree to which existing floodplains and wetlands attenuate flood peaks is a key area for further investigation and could be quantified through subsequent hydraulic modelling; this may explain a buffering of the flashy nature of the headwaters.

Contributing factors to flashiness include:

- Compact soils under pasture and access tracks limiting infiltration.
- Short hillslope-to-stream distances as in the steep upper catchment.
- Limited riparian vegetation along drainage networks.

5.4 Integrating Flow Insights into NbS Design

The hydrological patterns observed — particularly FRE3 timing, seasonal peaks, and flood recession behaviour — reveal two key periods of stress in the Taumārere catchment where NbS can offer targeted, meaningful support.

1. Buffering Early Dry Season Stress (Apr–May)

This period is becoming increasingly dry, with fewer high flows and longer recession limbs. Without adequate soil moisture recharge, catchments enter winter in deficit — delaying wetland activation and disrupting critical ecological triggers such as tuna (longfin eel) migration.

NbS Intention:

- Wetland expansion to improve moisture retention
- Infiltration zones in mid-catchment areas
- Reforested gullies to slow runoff and promote soil storag

2. Managing Flashy Summer Storms (Jan–Mar)

While baseflows are at their lowest, this period also brings sharp convective storms that produce fast-rising hydrograph peaks. These events cause erosion, bypass infiltration zones, and move large sediment loads — especially in modified or compacted landscapes.

NbS Intention:

- Leaky barriers to attenuate flashy runoff
- Swales and silt traps to filter and slow flow
- Riparian planting to cool water and reduce thermal shock

6 Summary and Recommendations

This analysis indicates the **Taumārere catchment is characterised** by the following

- Rainfall patterns are **increasingly volatile**, with large swings in seasonal totals from year to year.
- Rainfall is often intense, driving floods and runoff risks.
- **Q2–Q3 (spring–summer) are trending drier**, increasing drought stress and reducing baseflows.
- **Catchment response to rain is "flashy"**, meaning stream levels can rise quickly.
- **Flood recession is also relatively rapid**, offering reduced time for infiltration or habitat connection.
- **Farmers face unpredictability** in timing pasture growth, soil moisture, and stock planning.
- The data suggests that migration cues for tuna and aquatic species are now linked to fewer, more intense rainfall events later in the year.

6.1 Recommendations – NbS to Improve Catchment Resilience

The hydrological analysis exposed the instability of the regime and underscores the need to slow water down, reconnect floodplains, and buffer ecosystems from both drought and flood extremes. NbS can be used to address flashiness, sediment mobilisation, habitat disconnection, and water quality loss.

Potential actions could include:

- **Floodplain Reconnection**: Restore connections between river channels and adjacent lowlands to reduce flood peaks and enhance groundwater recharge.
- **Wetland Creation and Restoration**: Focus on persistently wet paddocks and drainage-prone areas to intercept runoff, trap fine sediment, and help maintain baseflows into summer.
- **Gravel Road Sediment Traps**: Use green infrastructure like silt traps or vegetated buffers near unsealed road discharge points, especially where greater than 10 mm/hr rainfall events cause fine sediment wash-off.
- **Leaky Barriers in Steep Sub-catchments**: Intercept short-duration storm pulses and reduce gully erosion in upstream areas.
- **Riparian Planting and Buffering**: Shade channels prone to low flows to protect aquatic habitat and cool stream temperatures.
- **Ecological Timing**: Use rainfall monitoring to time restoration works with tuna migration cues and avoid dry-season planting failures.

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Tonkin + Taylor Coastal Flood Hazard Assessment for Northland Region 2019-2020 report Prepared for Northland Regional Council Prepared by Tonkin & Taylor Ltd Date March 2021 Job Number 1012360.1000.v4

Appendix

Table giving the Seasonal FRE3 Event Count for the Waiharekeke Flow Gauge

Year/ Season	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun
1995	14	15	3	2
1996	25	5	4	6
1997	29	15	18	5
1998	10	2	16	4
1999	30	27	7	5
2000	12	10	8	0
2001	30	0	4	0
2002	7	17	16	3
2003	27	14	3	0
2004	13	28	13	13
2005	10	3	0	0
2006	19	0	9	8
2007	0	8	3	1
2008	27	15	7	0
2009	18	26	4	0
2010	24	11	9	3
2011	15	28	14	0
2012	29	2	0	9
2013	16	29	15	3
2014	13	25	18	1
2015	29	10	24	6
2016	3	10	18	0
2017	27	22	12	13
2018	27	20	13	1
2019	7	6	9	0
2020	9	6	11	8
2021	27	29	2	0
2022	20	6	23	24
2023	29	19	8	9
2024	20	5	5	2
2025	17	19	3	1
AVG	14	15	3	2

WET	NORMAL	DRY

Chart showing Long-term Rainfall Seasonality in NZ Hydrological Years