Integrated Stream Restoration and Design Guidelines

This guiding document provides a framework for stream reconstruction and enhancement, combining high-level ecological principles with practical design specifications to achieve resilient, biodiverse waterways.

1. Hydrology & Channel Geomorphology

The foundation of a healthy stream is a natural, continuous flow and a variable channel structure that supports both aquatic life and flood management.

- **Surface Flow & Continuity:** Maintain a continuous layer of water and preserve upstream-downstream connectivity (of bed level, substrate, and flow) to prevent barriers and fish stranding, allowing species to move freely even at low flows.
- **Meander Patterns:** Encourage natural planform variation. Intersperse sharper bends (to create deep, complex pools) with longer, gentler bends (to create shallow margins and increase lateral connectivity to floodplains and wetlands).
- **Riffle, Run, Pool Sequences:** Implement a repeating sequence of riffles (for oxygenation and invertebrate habitat), runs (transitional feeding areas), and pools (for hydraulic diversity and thermal/depth refuge) approximately every 5–7 channel widths. Varying the widths of these features provides essential hydraulic diversity.
- **Floodplain Connection:** Reconnect the stream to its floodplain to manage flood flows, cycle nutrients, and create backwater connections via large woody debris or ephemeral channels.

2. Substrate & Bed Material

Using the right substrate maintains natural hydraulic roughness, provides shelter, and supports specific spawning requirements.

- **Material Selection:** Use local natural bed material (a river run gravel/cobble mix of varying sizes) to maintain continuity in texture and colour. Fines and organic material will naturally accumulate over time and should not need to be added during construction.
- **Depth and Compaction:** Ensure a substrate depth of at least 50 cm in riffles to support hyporheic zone functions and invertebrate colonization. Avoid compacting the substrate to allow water infiltration and subsurface flow.
- **Surface Complexity:** Ensure un-embedded cobbles (300mm or greater) are present on the surface across all habitat types, especially along stream edges. Incorporate larger rocks and boulders into runs and pools—individually or in clusters—to create flow complexity and refugia for larger species.

3. Instream Features: Woody Debris

Strategically placing woody debris mimics natural stream conditions, slows water, traps organic matter, and stabilizes banks without hard engineering.

- **Material & Types:** Use durable hardwood species. Logs with root wads offer the best stability and cover, while large logs (greater than one-third of the channel width) and branchy bundles provide excellent spatial heterogeneity.
- **Strategic Placement:**
    - *Riffles:* Place at margins to roughen flow without blocking the full span.
    - *Runs:* Place occasionally to break uniformity and slow velocities.
    - *Pools:* Add root wads or angled logs along banks to maintain scour and create overhead cover.
- **Anchoring:** Anchor wood securely using root wads, embedding it in banks, or backfilling with boulders to prevent it from washing away or creating unintended fish barriers (like weirs).

4. Riparian Vegetation & Margins

Planting native margins shades the channel, cools the water, supplies leaf litter, and links aquatic and terrestrial ecosystems.

- **Layered Planting Zones:**
    - *Toe of bank:* Plant species with dense, fibrous roots to stabilize banks and create submerged root mats for juvenile fish and insects to shelter.
    - *Mid-bank:* Plant to provide cover at higher flows, add structure, and contribute leaf litter/insect drop.
    - *Upper bank/Canopy:* Plant native canopy trees to cool water temperatures, recruit future large woody debris, and supply terrestrial invertebrates.
- **Shading:** Aim for approximately 70% canopy shading at maturity, leaving dappled gaps over riffle areas to allow light for periphyton and invertebrates.

- **Targeted Spawning Habitat:** On low-gradient banks around pools and runs, plant *Carex* species among low-growing ground covers at a height that will be inundated during bankfull flows to provide spawning habitat for kokopu species.

5. Key Ecological Outcomes

By applying these design principles, the stream restoration will reliably yield the following outcomes:

- **Swimmable Pathways:** Continuous, low-velocity routes that allow native fish—especially juveniles—to move without hydraulic barriers.
- **Refugia & Resilience:** Safe resting areas during high flows, thermal stress, or predation, alongside flood resilience where complex channels and vegetation dissipate energy and reduce erosion.
- **Robust Food Supply:** Natural substrates, retained organic matter, and riparian drop increase invertebrate abundance, supporting a rich food web.
- **Spawning Sites:** Stable gravel pockets, low-velocity zones, and specific vegetated margins support spawning for species like īnanga, bullies, and kōaro.
- **Restored Biodiversity:** A dynamic mosaic of habitats that promotes natural biodiversity and fosters critical terrestrial-aquatic connectivity.

Summary

Principles

- **Local natural bed material:** Use locally sourced substrate to maintain continuity in texture and color, support natural hydraulic roughness, and provide interstitial spaces for invertebrates without altering natural sediment dynamics.
- **Surface flow:** Maintain a continuous layer of water along the stream bed to ensure fish can move freely, even during low flows, preventing stranding and velocity barriers.
- **Continuity:** Ensure smooth hydraulic and geomorphic transitions (in bed level, substrate, and flow) to prevent barriers, maintain sediment transport, and allow fish to navigate structures naturally.
- **Natural meanders:** Encourage planform variation to create a mix of deep pools, riffles, and slack-water zones, which increases habitat diversity and connects the stream to its floodplain.
- **Complex flows:** Introduce variability in depth, velocity, and turbulence to mimic natural conditions, provide diverse microhabitats, and reduce uniform high-velocity areas.
- **Place woody debris:** Strategically install logs and branches to create cover, trap organic matter, slow water locally, form pools, and naturally stabilize banks.
- **Plant margins with overhanging species:** Use native riparian vegetation to shade and cool the water, supply leaf litter (food), provide structural overhanging refuge for fish, and stabilize the stream banks with root systems.
- **Long-term Stewardship & Resilience:** Plan for climate change impacts (like floods and droughts), manage human impacts (like stormwater runoff), and engage stakeholders to ensure the stream's long-term ecological protection.

Outcomes

- **Swimmable pathways:** The creation of continuous, low-velocity routes that allow native fish—especially juveniles and weaker swimmers—to navigate the stream without hydraulic barriers.
- **Refugia:** Safe resting areas created by woody debris, vegetation, and complex flows that protect aquatic life during high flows, predation, or thermal stress.
- **Food supply:** A richer food web supported by increased invertebrate abundance and drift, which is driven by natural substrates, retained organic matter, and riparian vegetation.
- **Spawning sites:** The provision of stable gravel pockets, low-velocity zones, flood terraces and vegetated margins that serve as crucial spawning habitats for native species like īnanga, kōaro, and bullies.
- **Natural biodiversity:** A restored, resilient ecological function driven by a mosaic of habitats that supports a complete range of native fish, invertebrates, and riparian flora.
- **Flood resilience:** Improved system performance during storm events, as complex channels, vegetation, and woody debris dissipate energy, reduce erosion, and temporarily store floodwaters.
- **Terrestrial connectivity:** The creation of stable margins and riparian corridors that link aquatic and terrestrial ecosystems, allowing safe movement for birds, insects, and other fauna.

Guidance Document:

Integrating Woody Debris in Stream Restoration

Core Principles for Woody Debris Design

Large woody debris, in the form of logs or whole trees, is an important component of natural streams. Aquatic organisms, and fish in particular, have evolved to take advantage of the characteristics of logs etc that differs from rock boulders. The ability for fish of many sizes to seek refuge under or beside woody debris is an aspect that boulders alone do not usually offer.

Manually placing woody debris is an interim measure, intended to remain until trees and branches naturally fall into the stream or are carried downstream from other locations. The size and configuration of added debris will depend on site specific characteristics.

1. Material Selection and Sizing

- Use Durable Wood: Prioritise hardwood species to ensure the longevity and durability of the instream structures.
- Vary Wood Types: Incorporate different structures, focusing on logs with root wads for the best stability and cover, and large logs that span greater than one-third of the channel width. Branchy bundles can be added as supplementary cover, though they are less stable on their own.
- Plan for Future Recruitment: Plant native canopy trees on the upper stream banks to act as a natural, long-term source of future large woody debris.

2. Strategic Placement and Spatial Heterogeneity

- **Distribute for Complexity: Place wood strategically along banks, mid-channel, aligned with the flow, across the flow, or in cluster jams to create a diversity of flow velocities and depths.**
- **Targeted Habitat Placement:**
- *Riffles:* Place wood along the margins to roughen the flow, ensuring you avoid blocking the full span of the channel.
- *Runs:* Introduce wood occasionally to break up uniform water patterns and slow down velocities.
- *Pools:* Install angled logs or root wads along the banks to create overhead cover and help deepen or maintain scour pools.
- *Floodplain Connections:* Utilize large woody debris to help form backwater sections that connect the permanent stream channel to its ephemeral floodplain.

3. Secure Anchoring and Integration

- Anchor Firmly: Fix the wood securely to the bed or banks to prevent it from being washed away during high flows. This can be done by embedding logs into the banks, utilizing the natural anchoring of root wads, or backfilling the structures with boulders.
- Integrate with Vegetation: Plant root-wad forming vegetation near the woody debris to naturally anchor the wood in place over time and further enhance fish habitat.

4. Maintain Fish Passage

- Avoid Unintended Barriers: Ensure that the placement of wood does not obstruct the passage of expected fish species, specifically avoiding configurations that inadvertently create drops or artificial weirs.

Expected Ecological Outcomes

1. Enhanced Refugia

- Woody debris provides critical overhead cover and safe resting areas, offering aquatic life protection from predation, high flood flows, and thermal stress.

2. Increased Habitat and Flow Complexity

- The physical obstruction of logs and branches introduces necessary variability in water velocity and direction, mimicking natural conditions and reducing uniform, high-velocity zones.

3. Robust Food Supply

- Instream wood acts as a physical filter that traps organic matter, leaf litter, and fine sediment, which supports invertebrate colonization and drives a richer, more productive food web.

4. Stream Stability and Flood Resilience

- Strategically placed wood promotes natural channel morphology and stabilises banks without the need for hard engineering. During storm events, woody debris helps to slow flood flows, dissipate energy, reduce erosion, and direct flow to maintain essential channel features like scour pools.

Stream Restoration Checklist

1. Hydrology & Channel Geomorphology

- **Continuous Surface Flow:** Is there a continuous layer of water across the bed to ensure fish can move freely without encountering velocity barriers or stranding, even at low flows? **[Yes / No / Maybe]**
- **Smooth Transitions:** Are there smooth hydraulic and geomorphic transitions (in bed level, substrate, and flow) that allow fish to navigate structures and maintain natural sediment transport without abrupt barriers? **[Yes / No / Maybe]**
- **Variable Meanders:** Does the channel feature a mix of sharper bends (to create deep, complex pools) and longer, gentler bends (to create shallow margins and increase floodplain connectivity)? **[Yes / No / Maybe]**
- **Riffle, Run, Pool Sequences:** Does the stream contain a repeating sequence of riffles, runs, and pools approximately every 5–7 channel widths? **[Yes / No / Maybe]**
- **Hydraulic Diversity:** Is there variability in the widths of the riffles, runs, and pools to provide diverse hydraulic conditions and microhabitats? **[Yes / No / Maybe]**
- **Floodplain Connection:** Are there backwater sections that connect the permanent channel to its ephemeral floodplain, either through direct design or the placement of large woody debris? **[Yes / No / Maybe]**

2. Substrate & Bed Material

- **Local Material:** Is the substrate composed of locally sourced material with a river-run gravel and cobble mix of varying sizes to maintain natural texture and colour? **[Yes / No / Maybe]**
- **Substrate Depth:** Is the substrate layer at least 50 cm thick in riffle sections to support hyporheic zone functions and invertebrate colonisation? **[Yes / No / Maybe]**
- **Uncompacted Bed:** Is the substrate left uncompacted (with minimal fines added during construction) to allow for water infiltration and subsurface flow? **[Yes / No / Maybe]**
- **Surface Complexity:** Are un-embedded cobbles (300mm or greater) present on the surface across all habitat types, particularly along stream edges? **[Yes / No / Maybe]**
- **Boulders & Rocks:** Are larger rocks and boulders incorporated into runs and pools—placed individually or in clusters—to create flow complexity and refugia for larger species? **[Yes / No / Maybe]**

🪵 3. Instream Features & Woody Debris

- **Material Quality:** Is the woody debris made from durable hardwood species to ensure longevity? **[Yes / No / Maybe]**
- **Size & Type:** Does the debris include large logs (greater than one-third of the channel width) and logs with root wads for optimal stability and cover? **[Yes / No / Maybe]**
- **Secure Anchoring:** Is the wood securely anchored (e.g., using root wads, embedded into banks, or backfilled with boulders) to prevent it from washing away? **[Yes / No / Maybe]**

- **Strategic Placement:** Is the wood distributed to create spatial heterogeneity (e.g., at margins in riffles to roughen flow, occasionally in runs to slow velocities, and angled along banks in pools to maintain scour)? **[Yes / No / Maybe]**
- **Fish Passage:** Have you verified that the woody debris does not obstruct expected fish passage by creating unintended weirs or drops? **[Yes / No / Maybe]**

4. Riparian Vegetation & Margins

- **Layered Planting Zones:** Is vegetation layered to provide continuous habitat from the waterline to the upper banks, including the toe of the bank, mid-bank, and upper canopy? **[Yes / No / Maybe]**
- **Bank Stabilisation:** Are native plants with dense, fibrous root systems prioritised at the toe of the bank to stabilise the edges and create submerged root mats for aquatic shelter? **[Yes / No / Maybe]**
- **Shading Targets:** Is the planting designed to achieve approximately 70% shading of the channel at maturity, while leaving dappled gaps over riffles for periphyton and invertebrate growth? **[Yes / No / Maybe]**
- **Targeted Spawning Habitat:** On low-gradient banks around pools and runs, are *Carex* species and low-growing ground covers planted at a height that will be inundated during bankfull flows to support kokopu spawning? **[Yes / No / Maybe]**

5. Key Ecological Outcomes (Final Verification)

- **Swimmable Pathways:** Does the design provide continuous, low-velocity routes for native fish (especially juveniles and weak swimmers) to move up and downstream? **[Yes / No / Maybe]**
- **Refugia:** Are there sufficient safe resting areas during high flows, predation, or thermal stress? **[Yes / No / Maybe]**
- **Flood Resilience:** Do the complex channels, vegetation, and woody debris successfully dissipate energy, reduce erosion, and temporarily store water during storm events? **[Yes / No / Maybe]**