

TRANSPORTATION 2026 CONFERENCE

Designing Smarter Roads for a Resilient Tomorrow (This paper has been Peer Reviewed)

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ABSTRACT

Aotearoa New Zealand's transport network is vital to community wellbeing and economic resilience. In Marlborough, recent recovery efforts have demonstrated that resilience can be both visionary and grounded in practical, site-specific action.

The Marlborough Roads Recovery Team is a group of dedicated professionals who have come together to tackle some of the region's most challenging transport issues, including storm-damaged roads on geotechnically complex terrain.

The work through the Marlborough Roads Recovery Team has been a masterclass in doing more with less—retreating roads instead of building costly walls and tailoring pavement designs to geological conditions and local needs. Adapting stormwater systems to better handle shifting terrain and increased rainfall, integrating natural flow paths and flexible drainage solutions and using aerial mapping and GIS to guide slip remediation. These aren't just technical fixes; they're strategic moves that prioritise long-term stability and community wellbeing.

This paper will explore how resilience is embedded into every stage of transport recovery and design. If we can build resilient networks while anticipating future climate pressures, adapting to evolving landscapes, and creating systems that are lighter on the land – we can build a network that is stronger in the face of disruption and smarter in resource use. Marlborough's experience highlights the value of strategic decision-making under constraint, where limited resources have driven innovation and efficiency. The question left to answer then becomes; how can a council dealing with similar climate related issues begin if they want to adopt a similar recovery philosophy?

Marlborough's journey is a successful case that is seen as a microcosm of what transport networks across Aotearoa can become. This is not just about restoring connectivity—it is about building transport networks that are ready for the future.

1 WHY RESILIENCE MATTERS



Figure 1: Storm damage from July 2021 on Queen Charlotte Drive, (Marlborough District Council, 2021)

In the region of Marlborough at the Top of the South Island in New Zealand, two severe weather events occurred and exposed the fragility and vulnerability of the regions roading network. In July of 2021, a storm event caused widespread flooding and damage to the roads, results in over 1,600 faults on the network (NZTA, 2025). Queen Charlotte Drive, Kenepuru Road and the side roads of Kenepuru Sounds, Northbank Road, Wahopai Valley and Awatere Valley all became impassable, cutting off communities and impacting the safety of residents who relied on these roads (Marlborough Roads, 2021).

The initial response following the July 2021 storm was focused on rebuilding lifelines and providing support to the communities. The Marlborough Roads Recovery Team (MRRT) was born during this time and was established as a variation to the local Network Outcome Contract (NOC) (Marlborough Roads, 2021). The MRRT consisted of professional representatives from Marlborough District Council (MDC), NOC contractors and an assurance team. The newly formed MRRT worked diligently to understand the needs of the residents in the region by restoring road access for the communities with additional restrictions in place.

In August 2022, another severe weather event hit the region with over 670 km of the roads damaged (RNZ, 2025). As the storm dissipated, the full extent of damage was understood with over 4,000 faults identified. The repair costs soared from \$80 million NZD to \$400 million NZD, forcing a rethink of conventional approaches for remedial works (NZTA, 2025).

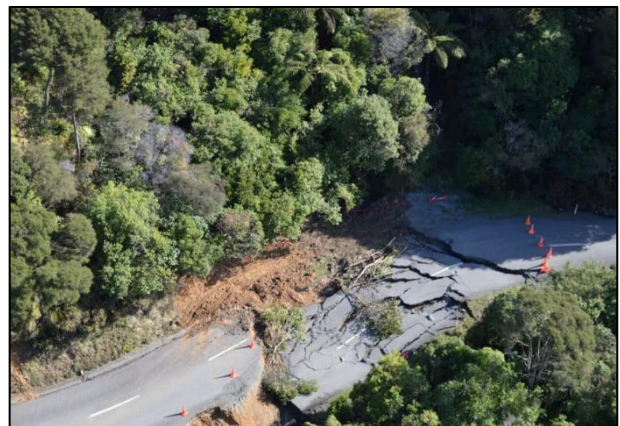


Figure 2: Storm damage from August 2022 on Kenepuru Road, (RNZ, 2023)

The storm events in Marlborough are an unfortunate case for the community, but a strong showcase to understanding that building a transportation network to be resilient is no longer optional - it is the future of sustainable infrastructure. The challenge that government and policy makers now face is focusing on continuing to restore connectivity while designing for a future that is likely to be impacted by more frequent and severe climate related events (Inside Government, 2025).

2 RESILIENCE AS A DESIGN PHILOSOPHY

Following the July 2021 storm event, the MRRT recognised that traditional approaches to road reinstatement were neither sustainable nor affordable. MDC was left trying to identify how to overcome the unknowns involved with restoring its community. The initial estimated bill for repairs was far beyond what MDC and Waka Kotahi NZ Transport Agency (NZTA) could fund (NZTA, 2025). This financial reality became a catalyst for innovation. Before NZTA was willing to commit to funding a large stage recovery project, MDC was required to undertake a comprehensive business case to determine appropriate service levels for each roading corridor (Marlborough District Council, 2021) (Stantec, 2023). This exercise was pivotal as it reframed recovery from a reactive process into a

more proactive and strategic design philosophy, centred on resilience.

The corridors are divided up based on geography, assess function, and risk profile.

- Queen Charlotte Drive (QCD) – A critical scenic and access route into the Sounds, heavily impacted by slips and underslips.
- Kenepuru Road and Side Roads – Serving remote communities and baches, this corridor faced severe geotechnical challenges and prolonged restrictions.
- Northbank Road – Inland corridor providing connectivity to forestry and rural communities.
- Waihopai Valley Road – Important for agricultural access and linking to State Highway 63.
- Awatere Valley Road – Serves farming communities and connects to SH1.
- State Highways (SH6 and SH63) – Strategic lifelines between Marlborough and Nelson, both closed during the August 2022 event.
- Other Sounds Access Routes – Including secondary roads and barge/water taxi-supported corridors identified in the Marlborough Sounds Future Access Study (MSFAS).

Each corridor was assigned a service-level guideline based on its importance, traffic volume, and resilience needs (Stantec, 2023). High-use corridors like SH6 and QCD were prioritised for robust reinstatement, while low-volume roads in geotechnically complex terrain were considered for reduced service levels or alternative access strategies (NZTA, 2025).

2.1 Level of Service Guidelines and Design Hub

The development of the Level of Service (LoS) Guideline was a cornerstone of the shift to resilient designs (Marlborough Roads, 2021). Initially drafted after the 2021 storm event, the document outlined different fault types, technical standards, and photographic examples to guide consistent design solutions. By mid-2022, the document had evolved to include standardised pavement and culvert designs, enabling replication across multiple sites with minimal investigation.

After the August 2022 storm event, the LoS Guideline document underwent significant refinement by a team of technical experts. Recognising the scale of work ahead, MRRT seconded specialists into a dedicated Design Hub (DH). The DH was tasked with managing and delivering design solutions efficiently. The DH consolidated technical expertise into one core team, rather than relying on dispersed resources or external consultants that required complex optioneering. The DH provided expert input on geotechnical, hydrological, and transport engineering challenges inherent in Marlborough's complex terrain. This structural change allowed the team to streamline workflows, reduce reliance on external tenders, and accelerate recovery works (Marlborough Roads, 2021).

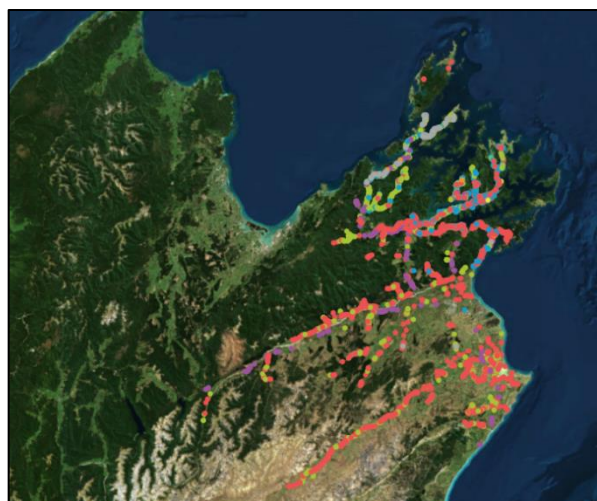


Figure 3: Top of the South Fault Map, MRRT Fault Database

2.2 Marlborough Sounds Future Access Study

The MSFAS was initiated after the August 2022 storm event. The study aimed to answer a critical question; *How can we maintain access to the Sounds in a way that is sustainable, cost-effective, and resilient to future climate pressures* (Stantec, 2023)? The study reinforced these principles by embedding hazard adaptation pathways and service-level hierarchies into long-term planning (Marlborough Roads, 2021). This ensured that recovery was not just about restoring connectivity but about designing smarter roads for a resilient tomorrow, with strategic options outlined for each corridor to anticipate future risk such as rainfall, slope instability and seismic activity (Scoop, 2021).

By understanding these characteristics, it meant that “repairing” the roads would have to integrate engineering, environmental stewardship, and community priorities. By embracing adaptability, efficiency, and integration, Marlborough transformed resource constraints into an opportunity for innovation, setting a benchmark for climate-responsive infrastructure across Aotearoa.

The MSFAS informed updates to the LoS guidelines to include precedence-based approaches for geometric design, standardised pavement and stormwater solutions, and pioneering frameworks for complex sites (Marlborough Roads, 2021) (Stantec, 2023). The study shifted the narrative of the damage of the storm events from “restore what was lost” to “design for what is coming”, encouraging people to think about flexibility and risk acceptance for different communities.

3 SMARTER DESIGNS IN ACTION

The MRRT faced thousands of roading faults across the geotechnically complex terrain (Marlborough Roads, 2021). Costs were continuing to escalate and there was immense pressure from the community to restore connectivity (RNZ, 2025). The traditional engineering solutions, such as a large retaining-wall and full-width reinstatement, were not affordable or sustainable.

3.1 Road Retreats over Retaining Walls

One of the most significant shifts in Marlborough’s recovery strategy was moving away from traditional retaining wall construction and moving toward road retreats. Retaining walls, while effective in stabilising underslips, can be expensive, resource-intensive, and often introduce long-term maintenance challenges—particularly in geologically complex terrain like the Marlborough Sounds. Instead, the recovery team adopted a more adaptive approach: realigning roads upslope to avoid unstable shoulders and slip-prone zones (Marlborough Roads, 2021).

This strategy delivered multiple benefits:

- **Cost Efficiency:** Road retreats are generally cheaper and faster to construct than engineered retaining walls, reducing financial pressure on recovery budgets.
- **Tighter Timeline:** Road retreats do not require specialised construction materials to complete. Often, work crews can mobilise quickly to a site with the right machinery ready to go.
- **Improved Resilience:** By relocating roads onto more stable ground, the risk of future failures is significantly reduced, creating a network better equipped to withstand heavy rainfall and seismic activity.
- **Environmental Sensitivity:** Retreating roads minimises the need for large-scale earthworks and imported materials, reducing ecological disturbance and heavy vehicle movements that can damage pavements.
- **Design Flexibility:** This approach allows for geometric adjustments, such as introducing single-lane sections, which further optimise space and cost without compromising safety.



Figure 4: Road retreat solution along Kenepuru Road

Rather than over-engineering with costly retaining walls, the team embraced road retreats which shifted alignments upslope to avoid unstable shoulders. This approach reduced costs, minimised environmental impact, and improved long-term stability. Similarly, adopting generic design templates for stormwater systems and shoulder repairs allowed rapid deployment while maintaining safety and ecological integrity. These strategies exemplify resilience as a design philosophy: anticipating future climate pressures, adapting to evolving landscapes, and creating systems that are lighter on the land.

3.2 Geometric Led Designs

In Marlborough's recovery, geometric-led design became a cornerstone of smarter, more resilient road engineering. Rather than restoring roads to their pre-storm dimensions, the recovery team adopted a precedence-based approach that prioritised safety, cost-effectiveness, and adaptability over rigid conformity (Marlborough Roads, 2021). This meant rethinking traditional design norms and instead tailoring solutions to the realities of steep terrain, limited budgets, and evolving climate risks.

Key elements of this approach included:

- **Single-Lane Sections:** Converting low-volume roads from two lanes to one where appropriate, reducing material requirements and minimising environmental disturbance.
- **Reduced Road Widths:** Aligning design standards with actual usage patterns and hazard profiles, rather than defaulting to full-width reinstatement.
- **Context-Specific Geometry:** Applying geometric principles to improve alignment and sight distances, ensuring safe travel even on constrained corridors.
- **Integration with LoS Guidelines:** Every geometric decision was guided by the updated LoS Guideline document, which provided clear standards for fault types, pavement design, and culvert sizing.

The benefits were significant:

- **Cost Efficiency:** Lower material volumes and simplified construction reduced financial strain.
- **Enhanced Resilience:** Narrower, well-aligned roads are easier to maintain and less vulnerable to future slips and storm damage.
- **Environmental Sensitivity:** Smaller footprints mean fewer earthworks, less imported fill, and reduced heavy vehicle movements—minimising ecological impact.

Geometric-led design reflects resilience as a philosophy: designing smarter roads that adapt to terrain and climate realities rather than imposing rigid, high-cost solutions. It demonstrates that resilience is not about building bigger—it's about building better, with flexibility and foresight.

3.3 Stormwater Systems for Dynamic Terrain

In Marlborough's steep, slip-prone landscapes, stormwater management is not a secondary consideration—it is a critical resilience factor. Traditional rigid drainage systems often fail under extreme rainfall or shifting terrain, leading to overtopping, erosion, and further instability. The recovery program embraced a smarter approach: stormwater systems designed for dynamic conditions, integrating flexibility, ecological sensitivity, and long-term adaptability (Marlborough Roads, 2021).

Key strategies included:

- **Natural Flow Path Integration:** Instead of forcing water into rigid channels, designs followed natural contours, reducing erosion risk and improving system performance during high-intensity storms.
- **Generic Stormwater Details for Rapid Deployment:** Standardised templates for channels, culverts, and headwalls allowed quick implementation across multiple sites without lengthy design cycles, while maintaining compliance with technical standards.
- **Sediment Capture and Scour Protection:** Systems incorporated sediment traps and scour protection measures to prevent blockages and downstream damage, particularly in areas prone to debris flows.
- **Fish Passage and Environmental Considerations:** Designs respected ecological requirements, ensuring connectivity for aquatic species and minimising habitat disruption.
- **Decision Flow Charts for Complex Sites:** Where generic solutions were insufficient, optioneering frameworks guided designers through site-specific assessments, balancing resilience, cost, and constructability.

The benefits were clear:

- **Adaptability:** Systems could be scaled or modified as terrain and climate conditions evolve.
- **Efficiency:** Standardised details reduced design time and resource use.
- **Resilience:** Improved drainage capacity and flexibility minimised the risk of future failures.

This approach reflects resilience as a design philosophy—working with the landscape rather than against it, anticipating variability, and embedding flexibility into every detail. By designing smarter stormwater systems, MRRT created infrastructure that is lighter on the land, better prepared for climate extremes, and aligned with environmental stewardship.

3.4 Standardised Design Templates

One of the most effective innovations in Marlborough’s recovery was the adoption of standardised design templates for common fault types and infrastructure elements. In a network with thousands of faults spread across geotechnically complex terrain, bespoke designs for every site would have been prohibitively slow and costly. Instead, the Marlborough Roads Recovery Team developed a suite of generic templates for pavement reinstatement, culverts, stormwater channels, road retreats, and shoulder repairs—creating a foundation for rapid, consistent, and resilient recovery (Marlborough Roads, 2021).

Why Standardisation Matters

- **Efficiency at Scale:** Templates allowed the Design Hub to replicate proven solutions across multiple sites without extensive ground investigations, dramatically reducing design time and cost.
- **Consistency in Quality:** Standardised details ensured compliance with technical standards and the updated LoS Guidelines, maintaining safety and performance across the network.
- **Flexibility for Adaptation:** While generic, these templates were designed to accommodate site-specific adjustments, enabling resilience without sacrificing speed.

Key Features

- **Pavement Design Modules:** Optimised for Marlborough’s varied geology, balancing durability with cost-effectiveness.
- **Stormwater and Culvert Details:** Incorporating sediment control, fish passage, and scour protection to meet environmental requirements.
- **Retaining and Shoulder Repair Systems:** Practical, repeatable solutions for minor and simple faults, reducing reliance on complex engineering for every site.
- **Resilience Benefits:** Standardisation is not about uniformity for its own sake—it’s about embedding resilience into the recovery process.

By using templates that anticipate common failure modes and integrate environmental safeguards, MRRT ensured that repairs were fast and future ready. This approach reflects resilience as a design philosophy: designing smarter roads through scalable solutions that adapt to terrain, climate, and resource constraints.

3.5 Technology Integration

Technology played a transformative role in Marlborough’s recovery, enabling smarter, faster, and more resilient solutions across a highly complex network. Rather than relying solely on traditional site inspections and manual assessments, the MRRT leveraged advanced tools and digital workflows to optimise design and delivery (Marlborough Roads, 2021).

Key Innovations

- **GIS and LiDAR Mapping:** High-resolution LiDAR and GIS datasets provided critical insights into terrain stability, slip-prone zones, and global movement patterns. These tools allowed engineers to identify hazards proactively, prioritise interventions, and design solutions tailored to site-specific conditions.
- **Digital Optioneering:** Complex sites required nuanced decision-making. Digital optioneering platforms enabled rapid comparison of remedial strategies—such as road retreats versus retaining walls—balancing resilience, cost, and environmental impact.
- **Standardised Digital Templates:** The Design Hub utilised digital libraries of standardised design templates for pavement, culverts, and stormwater systems. This streamlined design workflows, reduced duplication, and ensured consistency across hundreds of fault sites.
- **Remote Collaboration Tools:** With multiple agencies and contractors involved, cloud-based platforms facilitated real-time collaboration, document sharing, and version control—critical for maintaining governance and transparency.
- **Resilience Benefits:** Technology integration was not just about efficiency—it was about embedding resilience into every decision. By using data-driven insights and digital tools:
 - **Risk Management Improved:** Early identification of global movements and high-risk zones reduced reactive fixes and costly surprises.
 - **Design Speed Increased:** Automated workflows and templates accelerated delivery without compromising quality.
 - **Futureproofing Enhanced:** Digital models allowed scenario planning for climate-driven hazards, ensuring designs could adapt over time.

This approach reflects resilience as a design philosophy: leveraging technology to anticipate risks, optimise resources, and create smarter roads that endure in the face of uncertainty.

4 GOVERNANCE FOR RESILIENCE

These smarter designs demonstrate resilience as a design philosophy, anticipating future climate pressures, adapting to evolving landscapes, and creating systems that are lighter on the land yet stronger against disruption. Marlborough's approach shows that innovation under constraint can deliver not only recovery but a case study for future-ready transport networks. Smarter roads require smarter governance. The MRRT implemented:

4.1 Risk Acceptance Frameworks

Risk Acceptance Frameworks were central to this approach. Rather than insisting on high-cost, high-specification designs for every site, clients agreed to approve lower design levels where appropriate (Marlborough Roads, 2021). This calculated risk-taking allowed faster delivery and broader coverage across the network. It also acknowledged the reality of resource constraints while embedding resilience principles—prioritising function and safety over rigid conformity.

4.2 Transparent Fault Triage

With thousands of faults ranging from minor slips to complex geotechnical failures, MRRT introduced a clear categorisation system:

- Minor faults handled by contractors without design input.
- Simple faults managed by the in-house Design Hub using standardised templates.
- Complex faults required optioneering and specialist design.

This triage system streamlined approvals, reduced bottlenecks, and ensured that resources were allocated where they were most needed (Marlborough Roads, 2021). It also provided clarity for stakeholders, contractors, and the public, reinforcing trust in the recovery process.

4.3 Zonal Resource Consents

Governance extended beyond technical decisions to environmental and cultural responsibilities through Zonal Resource Consents. These consents addressed ecological impacts, fish passage, archaeological considerations, and iwi engagement. By embedding these requirements into the recovery framework, MRRT ensured that resilience was holistic, protecting not only infrastructure but also the natural and cultural landscapes it serves.

4.4 Smarter Roads Require Smarter Governance

Strong governance also underpinned funding success. NZTA's commitment to fund 95% of nearly \$53 million for Phase 2 recovery was contingent on these governance measures, demonstrating the link between structured decision-making and financial support. Transparent processes reassured stakeholders that public funds were being used responsibly and strategically.

Ultimately, smarter roads require smarter governance—systems that balance urgency with accountability, enable flexibility without chaos, and integrate technical, environmental, and community priorities (Marlborough Roads, 2021). Marlborough's experience shows that governance is not an administrative layer; it is a resilience enabler, turning disruption into an opportunity to build a network that is stronger, smarter, and ready for tomorrow

5 RESILIENCE DELIVERED

The true measure of resilience is not in design intent but in real-world performance under stress. Marlborough's recovery program, built on smarter design principles and robust governance, faced its first major test during the June/ July 2025 storm event, a significant weather event that brought heavy rainfall and renewed pressure on the region's fragile roading network. This event provided critical insight into how the completed works behaved and validated the philosophy underpinning the MRRT.

5.1 Ahead of Schedule and Under Budget

By mid-2025, recovery works were already projected to finish two years ahead of the original timeline and trending below initial cost estimates (RNZ, 2025). This efficiency was achieved through strategies such as road retreats, geometric-led design, standardised templates, and in-house delivery via the Design Hub. These measures were not only cost-effective but also embedded resilience into every decision, ensuring that the network could withstand future shocks without requiring expensive, reactive interventions.

5.2 Performance During the June/July 2025 Rainfall Events

When the June/ July 2025 rainfall events hit, the repaired corridors, including Queen Charlotte Drive, Kenepuru Road, and inland routes were subjected to intense rainfall and saturated ground conditions. Unlike previous events where widespread failures occurred, the newly implemented designs demonstrated remarkable stability:

- Road Retreats proved their worth by relocating alignments away from unstable shoulders, reducing underslip failures and maintaining carriageway integrity.
- Geometric-Led Adjustments, such as single-lane sections and optimised curves, minimised stress on pavements and improved drainage performance.
- Stormwater Systems designed for dynamic terrain handled increased runoff effectively, with flexible channels and sediment capture preventing overtopping and erosion.
- Standardised Pavement Designs showed durability, with minimal cracking or deformation

despite prolonged saturation.

While minor surface scouring and debris accumulation occurred in isolated areas, a predictable outcome in steep terrain, these were quickly addressed through routine maintenance rather than emergency interventions. Importantly, no major structural failures were reported, and access was maintained across all critical corridors, safeguarding communities and supply chains.

5.3 Future-Ready Network

The MSFAS played a pivotal role in this success by embedding hazard adaptation pathways and service-level hierarchies into planning. These frameworks ensured that recovery investments were not short-lived fixes but strategic moves toward a network that anticipates climate variability and evolving risk profiles.

6 LESSONS FOR DESIGNING SMARTER ROADS

Marlborough's recovery journey offers a powerful set of lessons for other councils who are dealing with similar issues when it comes to rebuilding transport networks that can withstand disruption and adapt to future challenges. At the heart of these lessons is the principle of designing for change. Resilience demands flexibility—roads must be planned and constructed with the understanding that hazard profiles will shift over time due to climate variability, seismic activity, and evolving land-use patterns. This means embedding adaptability into design standards, such as allowing for road retreats instead of rigid retaining walls and incorporating hazard adaptation pathways that enable staged responses rather than costly over-engineering.

Equally important is the need to prioritise function over form. In a resource-constrained environment, insisting on traditional two-lane configurations or high-specification designs for every corridor is neither practical nor sustainable. Marlborough demonstrated that accepting lower service levels, such as single-lane sections on low-volume roads, can maintain essential connectivity while reducing costs and environmental impact. This approach reflects a shift from perfection to pragmatism, ensuring safety and continuity without unnecessary complexity.

Technology plays a critical role in resilience. By leveraging GIS, LiDAR, and remote sensing, Marlborough's recovery team was able to identify slip-prone zones, monitor global movements, and prioritise interventions with precision. These tools transformed decision-making from reactive to proactive, enabling data-driven strategies that optimise resources and reduce risk. Digital optioneering and standardised design templates further accelerated delivery, proving that technology is not an add-on but a core enabler of smarter infrastructure.

Resilience also thrives on collaboration. Storm-damaged roads are inherently multi-disciplinary challenges, blending geotechnical, hydrological, and transport engineering considerations. Marlborough's success was built on integrating expertise across disciplines, ensuring that solutions addressed not only structural stability but also stormwater management, environmental protection, and community needs. This collaborative model fosters holistic resilience, where technical, ecological, and social priorities align.

Innovation under constraint is a defining feature of Marlborough's approach. Limited budgets and tight timelines forced the team to rethink conventional practices, leading to breakthroughs such as in-house design hubs, generic templates, and risk acceptance frameworks. These innovations demonstrate that scarcity can be a catalyst for creativity, driving efficiency without compromising resilience.

Together, these insights form a framework for future-ready transport networks: flexible, functional, technology-enabled, collaborative, and innovative. Marlborough's experience proves that resilience

is not a static goal—it is a dynamic design philosophy that anticipates change, embraces complexity, and delivers smarter roads for a more resilient tomorrow.

7 CONCLUSION

Resilience is not a destination, it is a design philosophy that transforms infrastructure from a brittle system into a living network, capable of adapting, integrating, and enduring. Marlborough's recovery journey demonstrates that smarter roads are those designed with foresight, flexibility, and integration. By embedding resilience into every decision, the MRRT delivered a network that is lighter on the land, stronger against disruption, and ready for tomorrow's challenges.

The success of Marlborough's approach lies in its ability to innovate under constraint. Faced with thousands of faults, escalating costs, and complex terrain, MRRT shifted from traditional engineering solutions to smarter strategies: road retreats instead of retaining walls, geometric-led design to optimise alignment and reduce footprint, stormwater systems tailored for dynamic terrain, and standardised templates for rapid, consistent delivery. These measures were supported by technology integration of GIS, the use of LiDAR, and digital optioneering, which enabled proactive risk management and accelerated design workflows.

Governance was equally critical. A risk acceptance framework allowed pragmatic decisions, transparent fault triage streamlined approvals, and zonal resource consents ensured environmental and cultural considerations were embedded in every stage. This structured approach secured NZTA's funding commitment and maintained public trust, proving that governance is a resilience enabler, not an administrative burden.

Performance during the June/ July 2025 storm validated these principles. Roads held firm, stormwater systems functioned effectively, and access was maintained across critical corridors. Minor issues were resolved through routine maintenance rather than emergency interventions marking a clear indicator that resilience was delivered, not just promised.

8 RECOMMENDATIONS

Marlborough's recovery provides a clear roadmap for designing smarter, climate-resilient transport networks. The first principle is to embed flexibility into design standards, ensuring roads can adapt to shifting hazard profiles and future climate pressures through staged responses rather than rigid, high-cost solutions. Equally important is to prioritise function over form, accepting lower service levels, such as single-lane sections on low-volume roads, to maintain connectivity while reducing costs and environmental impact. Technology is a critical enabler of resilience. By leveraging GIS, LiDAR, and digital design tools, planners can identify risk zones, optimise alignments, and accelerate delivery through data-driven decisions. Resilience also depends on collaboration. Integrating geotechnical, hydrological, and transport expertise ensures solutions are holistic, addressing structural stability, stormwater management, and community needs. Finally, Marlborough's experience shows that innovation under constraint is not a compromise but a catalyst for creativity, driving efficiency through standardised templates, in-house design hubs, and pragmatic risk acceptance frameworks.

Together, these principles form an outline for climate-responsive infrastructure that can be adapted by fellow councils across Aotearoa. Smarter roads, smarter governance, and a commitment to resilience as a guiding philosophy. Creating networks that are lighter on the land, stronger against disruption, and ready for tomorrow's challenges.

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AUTHOR CONTRIBUTION STATEMENT

This report was written by one author with insights from various reports, documents and studies completed over the course of the Marlborough Recovery works.