To NbS or not? That is the question

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Key points

- Nature-based Solutions (NbS) can deliver meaningful bank stabilisation, erosion management, and catchment management benefits, but their performance and reliability are highly context-dependent, and they are not universally appropriate.
- Case study evidence demonstrates that hybrid solutions, integrating NbS with conventional engineering measures, often provide the most robust and risk-appropriate outcomes where hydraulic forces and geomorphic instability exceed the tolerance of vegetation-based approaches alone.
- NbS are typically most effective when implemented as part of a system of complementary measures across the catchment, rather than as a single intervention.

Abstract

Nature-based Solutions (NbS) are increasingly promoted as multifunctional interventions capable of delivering ecological, social, and economic co-benefits while addressing complex water and catchment management challenges. Within riverine and floodplain environments, NbS are increasingly used to support bank stabilisation, erosion management, and waterway rehabilitation while maintaining floodplain function and enhancing broader ecosystem outcomes. Yet, despite their growing prominence, the practical question facing many planners, asset owners, and policy makers remains: When is an NbS the right solution and when is it not? This paper examines the decision context surrounding the selection, design, implementation, and risks of NbS within contemporary water and catchment management frameworks. While flood resilience is an important consideration, the primary focus of this paper is the application of NbS to bank stabilisation and erosion management within riverine and floodplain systems

Drawing on recent examples of riverbank stabilisation, erosion mitigation, and floodplain management projects, we explore the conditions that influence NbS performance, longevity, and cost-effectiveness. These include hydrologic suitability, geomorphic stability, land availability, maintenance capacity, regulatory drivers, community expectations, and alignment with existing infrastructure. We also highlight scenarios where NbS may underperform or introduce unintended consequences, such as increased operational complexity, uncertain long-term function, or misalignment with organisational risk tolerances.

To support engineering and risk-based decision-making, we propose a structured assessment framework that emphasises integrated solutions and focuses on defining desired or acceptable outcomes first. The framework encourages transparent evaluation of trade-offs, consideration of hydraulic and geomorphic constraints, quantification of ecosystem service benefits, and clearer articulation of long-term monitoring requirements.

Ultimately, the use of NbS can be maximised through context-specific application supported by robust engineering, multidisciplinary collaboration, and adaptive governance. Asking "to NbS or not?" is therefore essential, not to limit innovation, but to ensure that NbS are positioned where they are most capable of delivering appropriate, meaningful, and measurable long-term benefits for both waterway stability and catchment resilience.

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Keywords

Nature-based Solutions (NbS), flood risk management, catchment management, hybrid infrastructure, risk-informed decision-making, adaptive management

Introduction

Nature-based Solutions (NbS) are increasingly being adopted in water and catchment management as multifunctional approaches capable of delivering ecological, social, and economic benefits. Their applications range from urban stormwater treatment systems to floodplain restoration, where they can serve as alternatives to, or complements for, conventional engineered infrastructure. The appeal lies in addressing complex challenges such as climate change, urbanisation, and biodiversity loss while enhancing system resilience and liveability.

While NbS are frequently promoted as flood mitigation measures, this paper focuses primarily on their role in bank stabilisation and erosion management within riverine and floodplain environments. Flood mitigation benefits may be realised as a secondary outcome; however, the principal objective of the case studies examined is the management of bank instability and erosion while supporting ecological and geomorphic function.

Despite growing uptake, uncertainty remains around when NbS are most appropriate and effective in practice. Decision-makers must navigate site constraints, performance variability, maintenance demands, and organisational risk tolerance, often without clear guidance. Consequently, NbS may be overapplied in unsuitable contexts or overlooked where they could provide significant benefits.

This paper examines the conditions influencing NbS suitability and performance for bank stabilisation and erosion management within floodplain systems, and asks: when is an NbS the right solution, and when are hybrid or conventional approaches more appropriate? It proposes a structured, risk-informed framework to support more transparent, outcome-focused decision-making in water management.

Background and context

NbS are approaches that work with or mimic natural processes to address water management challenges while delivering environmental, social, and economic benefits. In this context, NbS include interventions such as constructed wetlands, biofiltration systems, riparian restoration, and floodplain reconnection, often positioned as alternatives to or complements with conventional "grey" infrastructure. Their adoption reflects a broader shift towards integrated and resilient water management that prioritises multifunctionality.

Policy support, sustainability targets, and community expectations have accelerated the uptake of NbS in both urban and regional settings. However, implementation is often influenced by strategic intent as much as technical suitability, creating potential misalignment between objectives and performance.

A key challenge is that NbS are highly context-dependent, with outcomes influenced by site conditions, governance, and maintenance capacity. This variability complicates decision-making and highlights the need for structured approaches to assess when NbS are appropriate and effective.

Methodology / approach

This paper adopts a qualitative, case-based approach to examine the performance, limitations, and decision contexts associated with the application of NbS in flooding and catchment management. Rather than treating NbS as a singular or predefined solution type, the methodology focuses on how different interventions perform under varying hydrologic, geomorphic, and institutional conditions, and how design intent aligns with observed outcomes over time. The analysis is informed by practitioner experience and a review of selected projects representing a range of flood risk settings, intervention types, and implementation outcomes.

Three example projects were examined to illustrate contrasting applications of NbS, including their successes and limitations, and to highlight the role of adaptive learning in design evolution. The first case study draws on two sites within the **Hunter Valley (Hinton 2 – Paterson River and Singleton Pilot Channel)**, which together demonstrate a progression in design approach. At Hinton 2, a context-specific hybrid solution was implemented in which mature riparian vegetation was retained through targeted placement of rock revetment using barge-based construction methods. Early identification of constructability risks and close collaboration between designers and contractors enabled refinement of the approach, resulting in improved bank stability while preserving existing ecological function. This project demonstrates how conventional engineering materials can support NbS objectives when applied with precision and sensitivity to site conditions.

In contrast, the Singleton Pilot Channel site illustrates the limitations of NbS under high flood stage and high-velocity flow conditions. The installation of features such as fish snags in hydraulically unsuitable zones led to underperformance during large flood events. This outcome highlights the importance of aligning NbS selection with hydraulic conditions, particularly in high-energy environments where flow velocities and depths exceed the tolerance of certain ecological interventions. Together, these Hunter Valley examples emphasise the importance of learning from both successful and unsuccessful applications to inform future design.

The **Elizabeth Macarthur Creek (EMC)** project provides an example of an iterative, adaptive approach to balancing vegetation management with rock-based stabilisation. This case highlights the challenges in defining the boundary between "grey" and "green" infrastructure and supports the proposition that rock revetment can be considered an NbS when designed to facilitate vegetation establishment and support geomorphic processes. Rock revetment can support geomorphological processes when applied selectively and integrated with vegetation and natural channel functions. Rather than preventing all channel adjustment, targeted revetment can stabilise high-risk bank sections, retain mature riparian vegetation, encourage sediment deposition and revegetation, and provide sufficient stability for broader geomorphic recovery. In these circumstances, the revetment acts as an enabling component within a hybrid Nature-based Solution, supporting both flood resilience and natural river processes. However, excessive or inappropriate use of revetment can constrain channel evolution, transfer erosion pressures, and disconnect rivers from their floodplains, highlighting the importance of site-specific geomorphic assessment.

A third example from **Powells Creek** demonstrates a successful hybrid application of rock revetment integrated with vegetation establishment. In this case, bank stabilisation works were complemented by natural colonisation and revegetation, resulting in improved ecological function and enhanced local amenity, including benefits to adjacent active transport corridors and property values. This example reinforces the concept that appropriately designed structural interventions can enable NbS outcomes, supporting the principle that "if you build it, they will come" when underlying conditions are favourable.

Across all examples, project outcomes were assessed against a consistent set of criteria, including flood performance under design and extreme conditions, integration with catchment processes, maintenance requirements, and alignment with organisational objectives and risk thresholds. A key theme emerging from the analysis is the value of an adaptive engineering approach, where design practices evolve through iterative learning and feedback from real-world performance. Insights from these case studies informed the development of the structured decision framework presented in this paper, which emphasises outcome-led assessment, explicit consideration of uncertainty, and the role of hybrid solutions in achieving reliable and defensible flood mitigation outcomes.

Table 1 Example Projects using NbS

Project	Flood Context	Intervention Type	Key Outcome	Relevance to NbS Decision-Making
Hunter Valley (Hinton 2 – Paterson River Site)	Riverine flooding with bank instability	Hybrid solution: targeted rock revetment placed by barge to retain mature riparian vegetation where is exists	Improved bank stability while preserving existing ecological function	Demonstrates how conventional materials can support NbS objectives when applied in a context-specific and construction-sensitive manner
Hunter Valley (Singleton Pilot Channel Site)	High flood stage, high-velocity flow field	Predominantly NbS approach	Underperformance during large flood events	Illustrates limitations of NbS under extreme hydraulic conditions and the importance of matching solution type to flood risk and velocity regime
Elizabeth Macarthur Creek	Ongoing erosion and flood management pressures	Iterative hybrid approach balancing retaining vegetation with targeted rock use and planting within / around rocks	Improved stability through combined ecological and structural measures	Highlights that rock revetment can function as an NbS when designed to support vegetation establishment and geomorphic processes
Powells Creek	Urban channel subject to erosion and flood conveyance pressures	Hybrid solution: rock revetment integrated with vegetation establishment within and around rocks and natural colonisation	Improved bank stability, enhanced ecological function, and increased public amenity	Demonstrates that well-designed structural interventions can enable NbS outcomes, supporting adaptive, context-driven approaches that deliver both functional and co-benefit outcomes

Key factors influencing NbS performance

There are several key factors that must be considered as part of a NbS system.

Table 2 Key Factors Influencing NbS Performance

Factor Category	Key Considerations	Description / Relevance
Physical & Environmental Factors	Hydrologic suitability	Alignment with catchment hydrology, flow regimes, and design rainfall events
	Climate variability	Sensitivity to climate change impacts, extremes, and long-term variability
	Site conditions	Soil characteristics, topography, groundwater, ecological context, bank slope and height, active geomorphic processes.
Spatial & Infrastructure Constraints	Land availability	Adequacy of space for implementation, buffers, and future adaptation
	Integration with existing assets	Compatibility with existing grey infrastructure and asset systems
	Urban vs rural context	Differences in scale, density, access, and competing land uses
Operational & Institutional Factors	Maintenance capacity	Availability of resources, skills, and funding for ongoing commitment to management
	Ownership and governance	Clarity of asset ownership, responsibility, and decision authority
	Organisational capability	Experience, risk tolerance, and internal support/desire for NbS delivery
Regulatory & Social Drivers	Compliance requirements	Alignment with planning, environmental, and water regulations
	Stakeholder expectations	Influence of funders, regulators, and partner organisations
	Community acceptance	Public perception, use, and social licence to operate

When NbS may underperform

While NbS offer significant potential benefits, their performance is not guaranteed across all contexts. Unlike conventional engineered infrastructure, NbS are inherently variable and influenced by ecological processes, climatic conditions, and long-term management practices. In fluvial environments in particular, creek and riverbanks are dynamic systems subject to ongoing adjustment, erosion, and sediment transport. Interventions such as rock revetments may stabilise localised areas; however, they fundamentally alter channel behaviour and can transfer erosion or adjustment pressures elsewhere. As such, careful consideration must be given to geomorphic processes and to where changes within the system is likely to occur. Recognition of these dynamics, and a willingness to anticipate, monitor, and adapt to failure, is critical to successful implementation.

A primary challenge is the **uncertainty in long-term performance**. Many NbS rely on biological systems that evolve over time, making it difficult to predict how performance will respond to changing climate conditions, altered flow regimes, land use pressures, or ecosystem maturation. Limited long-term monitoring data further constrains confidence in design assumptions and lifecycle performance, particularly when compared to conventional infrastructure with more established design standards.

NbS can also introduce **greater operational and maintenance complexity**. While often perceived as low-maintenance, these systems frequently require ongoing vegetation management, sediment control, and adaptive interventions supported by specialised expertise. Often a key assumption for NbS is that vegetation can be fully established before the next flood comes through. Where maintenance responsibilities are poorly defined or organisational capacity is limited, system performance can deteriorate rapidly, undermining both functional outcomes and stakeholder confidence.

Performance under **extreme events** represents a further key risk. NbS that perform effectively under frequent or moderate conditions may be exceeded or fail during large flood events, prolonged droughts, or compound climate stresses. In high-energy environments, such as those characterised by high velocities or deep flood flows, certain NbS elements—such as instream structures or plantings—may not provide sufficient stability or reliability. In these contexts, reliance on NbS alone may not meet required levels of service, particularly where public safety or critical infrastructure is at risk.

Alignment with **organisational risk tolerance** is another important consideration. Asset owners and practitioners operating within regulatory or liability frameworks often require predictable, repeatable performance outcomes. The inherent variability and uncertainty associated with NbS may therefore be difficult to reconcile with deterministic design expectations unless explicitly accounted for within a risk-based framework.

Finally, there is a risk of **overpromising co-benefits without sufficient evidence**. While NbS are frequently associated with improvements in biodiversity, amenity, and ecosystem services, these outcomes are not always realised to the extent anticipated, particularly where projects prioritise symbolic or aspirational objectives over measurable performance. Failure to deliver expected benefits can erode stakeholder confidence and reduce support for future implementations.

These limitations do not diminish the value of NbS; rather, they reinforce the need for rigorous, context-specific assessment and adaptive engineering approaches. Transparent evaluation of risks, system behaviour, and trade-offs—combined with a willingness to learn from both success and failure—is essential to ensuring NbS are applied where they can deliver reliable, meaningful, and defensible long-term outcomes.

Decision framework

The decision framework presented in Table 1 provides a structured, risk-based approach for assessing the suitability of NbS within flooding and catchment management contexts. The framework is designed to support flood risk practitioners by requiring clear definition of flood hazards, performance objectives, and acceptable risk thresholds prior to solution selection. It incorporates a multi-criteria assessment process that evaluates both primary flood mitigation performance and broader enabling factors, including severity of flooding, expected effectiveness of intervention, environmental and social benefits, scalability, stakeholder priority, and implementation readiness. The relative importance of these criteria is reflected through weightings, which are not fixed but are intended to be determined by the engineer or asset owner based on site-specific objectives, risk tolerance, and project constraints. This framework can be used when assessing multiple sites to help determine which site is the most appropriate and also to determine appropriateness, where scores are low.

The framework guides systematic evaluation of catchment-scale hydrologic processes, site-specific constraints, and institutional considerations, ensuring that NbS are assessed alongside conventional and hybrid flood mitigation options in terms of reliability, lifecycle performance, and resilience under extreme events. By explicitly separating core flood risk performance (typically assigned higher weighting) from co-benefits, the framework enables transparent trade-off analysis and reduces reliance on outcomes that may be uncertain or difficult to quantify. The resulting weighted assessment supports a defensible decision pathway – especially when considering multiple sites for appropriateness. The weighted score indicates whether an NbS is suitable as a standalone solution, should be implemented as part of a hybrid approach, or is unlikely to meet required performance outcomes (or is unlikely to perform reliably). Where possible, preference should be given to interventions that protect or restore existing natural processes before introducing engineered or mimicked solutions.

NbS are typically most effective when implemented as part of a system or complementary measures across the catchment, rather than as a single intervention. Flooding is frequently the result of multiple interacting hydrological and geomorphological processes operating at different spatial scales, and therefore rarely responds to a single solution. A combination of measures that slow, store, infiltrate, and safely convey water can provide greater overall resilience than any individual intervention. For example, runoff management in upper catchments can be combined with riparian restoration, floodplain reconnection, bank stabilisation, and targeted engineered infrastructure in downstream locations. This approach distributes risk across multiple assets and processes, reduces dependence on the performance of any one measure, and enables greater flexibility under changing climatic and catchment conditions. The case studies examined in this paper demonstrate that hybrid systems, which combine natural and engineered elements, often provide the most reliable outcomes by balancing ecological benefits with the performance certainty required for flood risk management. As such, the question is often not whether to implement NbS or conventional infrastructure, but how the two can be integrated most effectively within the broader catchment system.

Table 3 Decision framework

Indicator	Assessment Focus	Scoring Criteria	Indicative Weight*
Severity of Flooding Issue	Magnitude, depth, frequency, and visibility of flooding	1 = Minor, localised flooding 2 = Noticeable, disruptive flooding 3 = Severe, frequent, high-impact flooding	10%
Flood Risk Mitigation Effectiveness	Ability of NbS to reduce flood depth and extent aligned with catchment hydrology and flow pathways	1 = Limited reduction 2 = Partial reduction 3 = Significant reduction	25%
Hydraulic and Geomorphic Suitability	Ability of the proposed NbS to withstand site-specific velocities, stream power, boundary shear stress, and erosion/scour processes	1 = Poor suitability: High erosion risk, high shear stress or stream power. NbS unlikely to remain stable without significant structural support. 2 = Moderate suitability: Moderate erosion and scour risk. Hybrid solution likely required. 3 = High suitability: Hydraulic conditions compatible with NbS performance. Minimal structural intervention required.	20%
Environmental Benefits	Ecosystem services and ecological uplift. Assess benefits to protect or restore existing natural processes before introducing engineered or mimicked solutions	1 = Minimal benefit 2 = Moderate enhancement 3 = Multiple measurable benefits	5%
Social Benefits	Amenity, safety, access, and public space value	1 = Minimal social value 2 = Improved usability 3 = Significant new social benefits	5%

Indicator	Assessment Focus	Scoring Criteria	Indicative Weight*
Upscalability and Replicability	Transferability across similar sites	1 = Site-specific 2 = Moderately transferable 3 = Highly replicable	15%
Stakeholder Priority	Alignment with Council, State, asset owner priorities, land ownership, and permissions	1 = Low priority 2 = Moderate interest 3 = High priority and alignment	10%
Implementation Readiness	Land tenure, ROW, constructability, regulatory approvals, and delivery feasibility	1 = Major constraints 2 = Manageable constraints 3 = Ready to proceed	10%

*Weightings are indicative only and should be adjusted by the engineer or asset owner to reflect site-specific objectives, constraints, and risk tolerance. Higher weighting is typically assigned to flood mitigation effectiveness to reflect primary objectives, i.e. flood risk reduction.

Discussion

The findings presented in this paper reinforce that NbS are not universally appropriate responses to flooding and catchment management challenges. While NbS can deliver valuable outcomes under suitable conditions, their effectiveness is highly dependent on site context, system scale, and organisational capacity. Treating NbS as inherently superior or universally applicable risks poor performance outcomes, increased uncertainty, and erosion of confidence among practitioners and asset owners.

A key insight is the importance of context-specific application. Catchment hydrology, land availability, climate exposure, governance arrangements, and maintenance capability all exert significant influence on NbS performance and longevity. Where these factors are not explicitly accounted for, NbS may underperform relative to conventional infrastructure or fail to meet required flood risk service levels. This underscores the need for structured, outcome-driven assessment rather than solution-led selection.

The analysis also highlights hybrid solutions as a realistic and often preferable pathway. Combining NbS with conventional bank stabilisation and erosion management measures can enhance system resilience by allowing natural processes to continue where appropriate while providing targeted protection where hydraulic forces or geomorphic instability exceed the tolerance of vegetation-based solutions alone. This approach avoids the distinction between "grey" and "green" infrastructure and recognises that engineered interventions can act as enabling measures that support ecological recovery, vegetation establishment, and broader catchment objectives.

This integrated approach has important implications for practitioners and decision-makers. For engineers, it requires a greater understanding of ecological and geomorphic processes and their incorporation into flood modelling, design, and risk assessment practices. Asset owners must balance long-term operational responsibilities, uncertainty management, and asset performance requirements while recognising the value of ecosystem services and adaptive management. Policy makers play a critical role in enabling flexible, evidence-based approaches that support context-specific solutions rather than prescriptive preferences for either conventional or nature-based interventions. Ultimately, the success of NbS depends less on the concept itself and more on how well solutions are aligned with site conditions, organisational objectives, and long-term governance and maintenance arrangements.

Conclusions

NbS represent a powerful and increasingly important component of contemporary flooding and catchment management, but they are not universally suitable. Their ability to deliver reliable flood mitigation outcomes is highly context-dependent and influenced by physical constraints, institutional capacity, and acceptable risk thresholds.

This paper demonstrates the importance of structured, risk-informed decision-making to support appropriate selection of NbS alongside conventional and hybrid solutions. By explicitly defining required outcomes, assessing uncertainty, and separating core performance requirements from aspirational co-benefits, decision-makers can more transparently evaluate trade-offs and manage expectations.

Integrating engineering and ecological thinking is essential to maximising the value of NbS while maintaining system reliability and accountability. Asking “NbS or not?” is therefore not a constraint on innovation, but a necessary step towards more resilient, defensible, and effective flood and catchment management outcomes.

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