



Systemic Value of Functional Based Clusters and Strategic Environmental Assessment Framework in Integrated River Basin Master Planning

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Article History; Received: 19 October 2025, Accepted: 23 April 2026, Published: 28 April 2026

Abstract

This article explores the systemic value of integrating the Function-Based Clusters (FBCs) and Strategic Environmental Assessment (SEA) framework into Thailand's river basin master planning. The FBC–SEA approach combines functional zoning (F1–F6 with sub-zoning) with strategic assessment processes, thereby linking spatial logic with systemic analysis. The study highlights five key dimensions of water management: domestic water supply, productive and economic uses, water-related disasters, water quality and environment, and governance and management. Drawing from empirical studies on risk mapping, SEA implementation, and participatory water governance, the analysis demonstrates that FBC–SEA enhances upstream–downstream causal reasoning, strengthens participatory governance through functional-zone forums, improves climate resilience by facilitating scenario development, and provides measurable outputs such as policy maps, indicators, and dashboards. Furthermore, risk maps superimposed on FBC zones identify vulnerable areas and enable spatial prioritization to achieve equity across urban, agricultural, and marginalized communities. In contrast, conventional SEA applied without spatial-functional integration tends to remain fragmented and less effective in capturing systemic relationships and more oriented toward short-term measures. The study concludes that adopting the FBC–SEA framework in full can transform river basin master plans into *living plans* that are transparent, adaptive, and aligned with global agendas such as the Sustainable Development Goals (SDGs) and the Paris Agreement.

Keywords : FBC–SEA; River Basin Master Plan; Risk Map; Governance; Climate Resilience; Sustainable Development Goals

Introduction

River basin management in Thailand has long been framed through the lens of Integrated Water Resources Management (IWRM), which emphasizes efficiency, equity, and sustainability [1]. Yet, challenges remain acute: rural households still lack reliable access to safe drinking water, conflicts over irrigation water allocations are intensifying, urban floods continue to paralyze major cities, and water quality degradation persists. These challenges highlight the inadequacies of fragmented governance and conventional problem-based planning.

Theoretical debates on the structure–function relationship of river basins provide a critical foundation for rethinking master planning. Watershed systems can be understood as an integrated assemblage of geomorphology, forest cover, and human settlement patterns, which fundamentally determine hydrological and ecological functions such as runoff regulation, groundwater recharge, and ecosystem service provision. The River Continuum Concept [2] describes how structural gradients from headwaters to large rivers condition ecological functions. Allan [3] emphasized the socio-ecological functions of river basins in linking ecosystems to livelihoods. Postel and Richter [4]

further linked water structure–function dynamics to sustainable water use.

Strategic Environmental Assessment (SEA) has been formally guided in Thailand by the National Economic and Social Development Council (NESDC), which defines SEA as a flexible and long-term strategic process supporting decision-making through balanced consideration of economic, social, and environmental dimensions, with strong emphasis on stakeholder participation and sustainability. The Function-Based Clusters (FBCs) and Strategic Environmental Assessment (FBC–SEA) framework proposed in this study does not replace or challenge the NESDC SEA process. Rather, it complements existing SEA practice by embedding SEA procedural steps within a spatially explicit functional zoning structure, thereby enhancing operational clarity, spatial prioritization, and replicability across river basins.

Within this conceptual frame, the FBC–SEA framework builds on both Thai and international traditions. By clustering river basin functions into six categories (F1 headwaters, F2 storage, F3 conveyance, F4 urban/economic zones, F5 agriculture, and F6 vulnerable areas) and embedding these clusters into SEA processes, FBC–SEA operationalizes the structure–function paradigm into practical planning.

This study contributes to Strategic Environmental Assessment and river basin planning literature by providing a spatially replicable operational framework that

systematically embeds SEA procedural steps within Function-Based Clusters, thereby bridging the gap between strategic assessment and spatial implementation in integrated river basin master planning.

Conceptual Background: IWRM, SEA, and FBC

Integrated Water Resources Management (IWRM) has served as a guiding principle in global and Thai water policy. Its integration framework seeks efficiency, equity, and sustainability, but its application has often been criticized as overly abstract. FBC–SEA can be seen as an operationalization of IWRM, turning general principles into spatially explicit and policy-relevant processes.

Strategic Environmental Assessment (SEA) is central to this process. SEA traditionally follows a cycle of scoping, scenario and impact analysis, trade-off evaluation, and mitigation design. However, without spatial functional clusters, SEA risks being reactive and fragmented.

Function-Based Clusters (FBCs) bring spatial clarity. By categorizing zones based on their systemic roles, FBCs provide an entry point for linking upstream–downstream causality with social and economic considerations. Sub-zoning allows further granularity, for example distinguishing peri-urban industrial clusters (F4B) from central business districts (F4A).

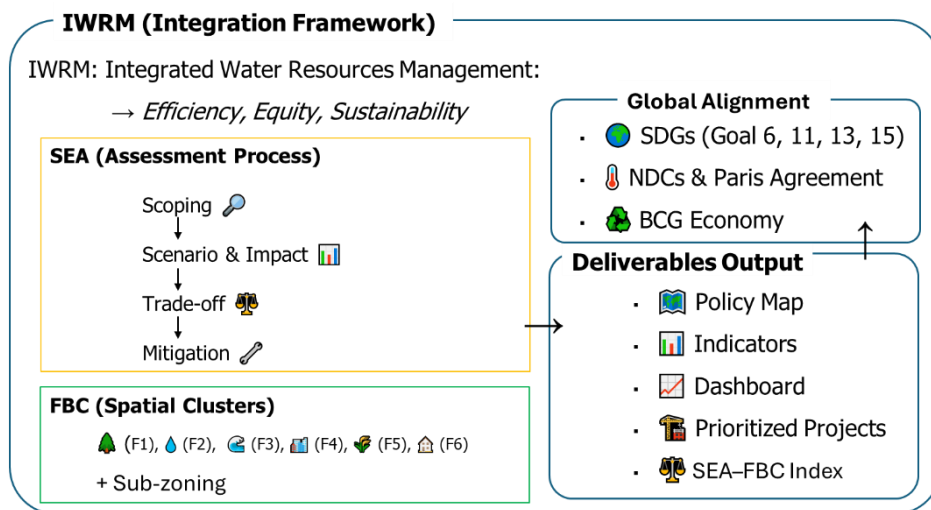


Figure 1 IWRM Integration Framework including SEA processes, FBC zones, global alignment, and deliverables

Methodology

This article applies a qualitative comparative analysis supported by literature review and empirical evidence. The methodology involves three steps:

First, theoretical perspectives on structure–function relationships were reviewed from Thai and international sources.

Second, a comparative framework was developed to contrast SEA-only approaches

with SEA combined with FBCs across the five water management dimensions: domestic supply, economic uses, disasters, water quality, and governance.

The analytical structure of this comparison is summarized in **Table 1**, which outlines how conventional SEA and FBC–SEA differ in addressing systemic relationships, spatial prioritization, and governance mechanisms across the five dimensions.

Table 1 Comparative Analytical Framework comparing Conventional SEA and FBC+SEA across five dimensions

Water Dimension	Conventional SEA (Non-spatial Integration)	SEA+FBC (Spatially Functional Integration)
Domestic Water Supply	Focuses on shortage areas only	Links upstream forest (F1) and storage (F2) to household water access
Productive & Economic Uses	Considers irrigation demand conflicts	Connects F5 agriculture & F4 urban zones to systemic allocation mechanisms
Water-related Disasters	Identifies flood/drought hotspots	Uses F1–F3 causal chains to design mitigation and adaptive scenarios
Water Quality & Environment	Monitors pollution in critical rivers	Integrates F6 vulnerable zones and ecological services into SEA
Governance & Management	Ad hoc participation; fragmented institutions	Functional participatory forums per FBC; systemic monitoring dashboards

Third, empirical cases were synthesized, including flood hazard mapping in Nakhon Ratchasima [5], participatory water governance in Southern Thailand [6], and urban water dashboards in Lamphun [7]. This procedural framework is designed to be transferable and replicable across river basins with comparable spatial datasets and planning contexts.

The procedural integration is further detailed in Box 1.

Box 1. Replicable Procedural Steps of the FBC–SEA Framework

Step 1: Basin Delineation and Spatial Data Assembly

River basin boundaries are delineated using GIS integrating topography, hydrology, land use, forest cover, settlements, and socio-economic indicators.

Step 2: Functional Classification into FBC Zones (F1–F6)

Spatial units are classified into six clusters reflecting structure–function relationships.

Step 3: SEA Screening and Scoping by Functional Zone

Strategic issues and sustainability indicators are identified per zone following NESDC SEA guidelines.

Step 4: Scenario and Alternative Development

Alternatives are formulated using upstream–downstream causal logic.

Step 5: Strategic Assessment and Sustainability Measures

Options are evaluated across economic, social, and environmental dimensions.

Step 6: Participatory Validation and Decision-making

Functional forums validate alternatives and support planning consensus.

Step 7: Outputs, Monitoring, and Replication

Policy maps, indicators, and dashboards are generated for basin-wide monitoring.

This framework operationalizes SEA within a spatial-functional architecture, ensuring replicability and policy relevance.

Results and Discussions

Structure–Function Logic

The structure–function paradigm is evident in the FBC design. F1–F2 clusters reflect natural structures regulating water quantity, while F4–F5 clusters highlight socio-economic structures. F6 clusters capture vulnerable communities structurally exposed

to risk. By aligning SEA assessments with these clusters, causal chains from upstream forest loss to downstream flood vulnerability become clear. These findings indicate that integrating FBC with SEA enhances the ability of strategic planning to capture upstream–downstream causality, spatial differentiation, and governance coherence compared to conventional SEA approaches.

Function Based Cluster	STRUCTURE	FUNCTION
 F1 headwaters	Forest / Headwaters 	Infiltration, baseflow, ecosystem services
 F2 reservoirs and wetlands	Storage 	Seasonal regulation, drought buffering
 F3 rivers and floodways	Conveyance 	Flow transport, sediment balance, flood pathways
 F4 urban/economic zones	Urban / Economic Zones 	Water demand, pollution, governance pressure
 F5 agricultural lands	Agriculture 	Irrigation use, food security, rural livelihoods
 F6 vulnerable areas	Vulnerable Areas 	High exposure to floods/droughts, equity, adaptive capacity

Figure 2 Conceptual diagram mapping FBCs to structure–function relationships

Empirical Evidence: Risk Mapping

Flood hazard maps and risk assessments in Thailand illustrate the systemic value of FBCs. For example, risk maps of the Mun River Basin combine hydrological and socio-economic layers, identifying high-risk agricultural zones. Bangkok flood risk studies [8] reveal inequities in exposure across districts. Integrating these risk maps into FBC zones enables prioritization of interventions.

Governance and Participation

FBCs create platforms for inclusive participation. Farmers in F5 zones, urban residents in F4 zones, and marginalized groups in F6 zones can each engage in governance forums tailored to their realities. Empirical research in Southern Thailand shows that participatory forums improve trust and reduce conflict [6]. The Bangkachao case demonstrates how

peri-urban community voices strengthen environmental governance [9].

Climate Resilience and Scenarios

Scenario analysis is strengthened by FBC–SEA. For example, in the Chao Phraya Basin, studies highlight the need to combine diversion canals (grey infrastructure) with retention wetlands (NBS) for effective adaptation [10]. Economic assessments of NBS confirm cost-effectiveness in reducing flood risk [11].

Outputs and Monitoring

Deliverables of FBC–SEA go beyond project lists. Policy maps, indicators, and dashboards make systemic performance measurable. Case studies of Lamphun’s urban water dashboard [7] and Bangkok’s utility resilience [8] demonstrate practical monitoring applications.

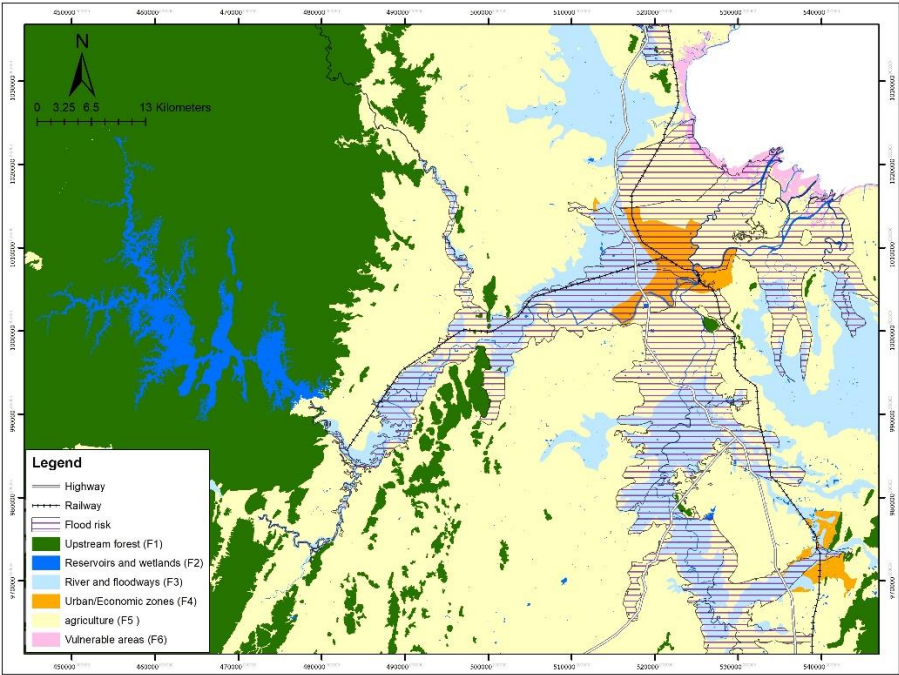


Figure 3 Sample risk map overlaid with FBC zones

Table 2 Scenario Comparison: Grey vs. Nature-Based vs. Integrated

Criteria	Grey Infrastructure	Nature-Based Solutions (NBS)	Integrated Approach (Grey + NBS + FBC–SEA)
Cost-effectiveness	High capital, high maintenance	Lower cost, co-benefits	Balanced cost with diversified benefits
Climate Resilience	Limited adaptability	High adaptability to variability	Highest resilience through redundancy
Social Acceptance	Moderate; often top-down	High; community-friendly	High; participatory and context-specific
Equity	Benefits urban/industrial zones	Benefits vulnerable & rural zones	Balanced across F1–F6
Policy Integration	Weak alignment with SDGs/Paris	Strong ecosystem alignment	Strongest alignment with SDGs, Paris, BCG

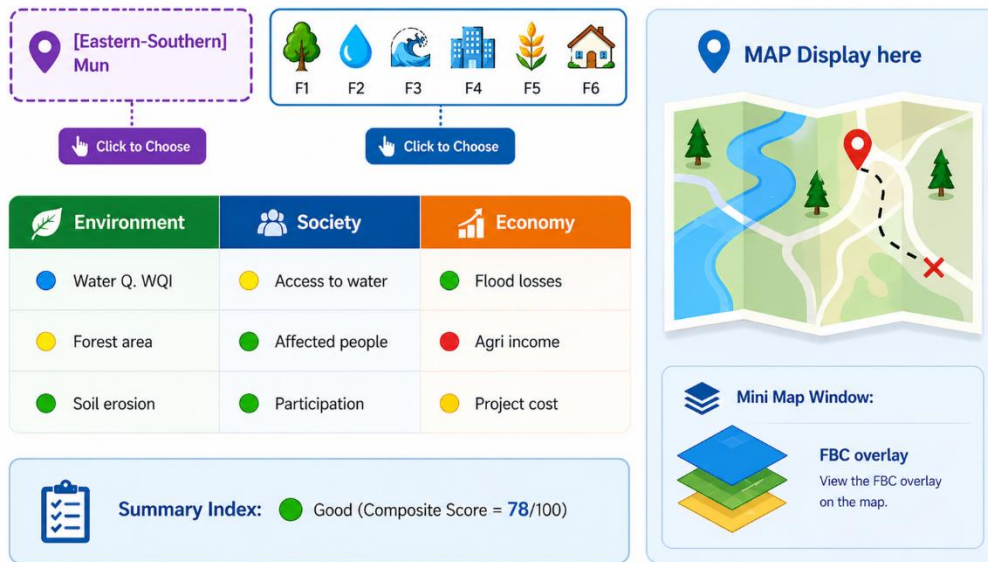


Figure 4 Example of dashboard concept aligned with FBC zones

Global Alignment

FBC–SEA outputs align with global agendas:

- SDG 6 on water, SDG 11 on resilient cities, SDG 13 on climate, and SDG 15 on ecosystems.
- NDCs and the Paris Agreement provide climate adaptation pathways

that can be operationalized through FBC–SEA.

- The Bio-Circular-Green (BCG) Economy strategy of Thailand resonates with FBC–SEA’s systemic and integrative approach.

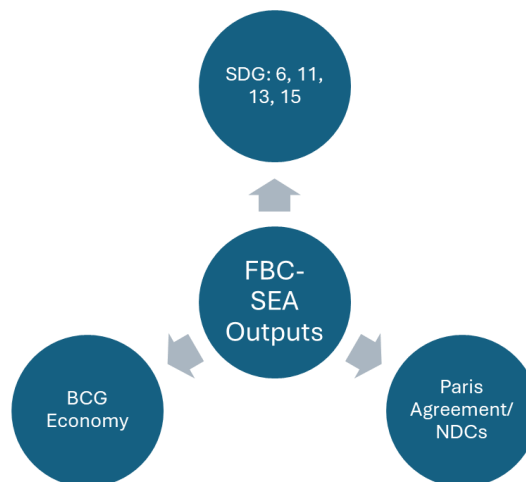


Figure 5 Alignment of FBC–SEA outputs with SDGs, Paris, BCG

Conclusions

Beyond conceptual integration, this study demonstrates how FBC–SEA translates SEA principles into actionable planning procedures, enabling functional prioritization, participatory decision-making, and measurable outputs such as policy maps and indicators. This positions SEA as an active planning engine rather than a compliance-oriented assessment tool.

SEA without FBCs can address immediate challenges but risks neglecting systemic upstream–downstream logic, equity, and resilience. In contrast, FBC–SEA integrates structure–function theory, risk-based evidence, participatory governance, scenario analysis, and measurable outputs. This transforms river basin master plans into *living plans*—transparent, adaptive, and globally aligned.

Policy Implications

1. Institutional adoption of FBC–SEA as a standard planning tool ensures systemic coherence in water management.
2. Integration of risk maps with functional zoning guides equitable spatial prioritization.
3. Development of indicators and dashboards makes basin performance measurable and transparent.
4. Creation of functional participatory forums ensures inclusiveness and reduces conflicts.
5. Linkage with global frameworks such as the SDGs, Paris Agreement, and BCG Economy elevates Thailand's credibility in international environmental governance.

Acknowledgements

The authors gratefully acknowledge Dr. Kobkiat Pongput for his valuable guidance and constructive insights, which significantly contributed to the conceptual clarity of this study.

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