Building Coastal Resilience to Safeguard Indonesia's Economic Backbone

A Tailored Approach for Giant Sea Wall Implementation

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Foreword

The Constitution of the Republic of Indonesia guarantees every citizen the right to live safely and with dignity. Nowhere is this right more at risk than along the coast of North Java, where millions face recurring threats from coastal flooding, land subsidence, and rising sea levels. These issues are not only humanitarian or environmental – they are economic as well. The North Java corridor is Indonesia's most productive and strategically vital region, home to major ports, power plants, industrial zones, and critical transport infrastructure that form the backbone of national competitiveness. Protecting this corridor is no longer optional; it is a national imperative.

Building resilience along the North Java coastline is about securing the foundations of Indonesia's economic future. Disruptions to logistics, manufacturing, and urban infrastructure along this coast would have cascading impacts far beyond the flood zone, affecting national gross domestic product (GDP), trade flows, job creation, and investor confidence. The proposed Giant Sea Wall, spanning 500 to 946 kilometres, is one of the most ambitious initiatives ever undertaken to protect both lives and livelihoods. It represents a pivotal opportunity not only to prevent loss but also to unlock value creation, foster vibrant communities, and stimulate new economic activities in the area.

This report is the result of close collaboration between Deloitte, Haskoning, Witteveen+Bos, and Foresight Works, that brings together global expertise in infrastructure strategy, coastal engineering, nature-based solutions, and artificial intelligence (AI) for complex program delivery. It offers a forward-looking roadmap to support the Government of Indonesia's vision for integrated coastal development, informed by international benchmarks and lessons from large-scale water infrastructure systems.

We would like to extend our sincere appreciation to all experts, stakeholders, and institutions who generously contributed their insights to this publication. We hope that it will serve as both a strategic reference and a practical guide for the government, private sector, and civil society to jointly accelerate the protection and transformation of North Java.

Ultimately, securing Indonesia's coastline is not only about defending land from the sea. It is also about preserving national productivity, enabling inclusive growth, and ensuring that Indonesia's most valuable assets – its people and its economy – can thrive for generations to come.

The time to act is now.

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Building Coastal Resilience to Safeguard Indonesia's Economic Backbone | A Tailored Approach for Giant Sea Wall Implementation

Executive summary

The North Java coastline is Indonesia's most valuable economic corridor, home to nearly 50 million people and a dense concentration of seaports, industrial estates, airports, logistics hubs, and metropolitan centres. It generates a substantial share of national GDP, employment, and trade. Yet, this prosperity is increasingly becoming threatened by intensifying coastal risks.

Land subsidence, tidal flooding, fluvial flooding, and rising sea levels – exacerbated by over-extraction of groundwater – are already disrupting major economic activities. In Jakarta, Semarang, and other coastal cities, annual flooding damages factories, halts port operations, and endangers lives and infrastructure. Without bold and coordinated action, these impacts will deepen, threatening long-term economic stability.

In this context, the Giant Sea Wall project has re-emerged as a flagship national initiative, championed by the President of Indonesia and the Coordinating Ministry of Infrastructure and Regional Development. Envisioned as a 500 to 946 kilometre coastal barrier stretching from Banten to Gresik, the project aims to safeguard vulnerable communities, protect critical economic assets, and foster climate-resilient growth along the north coast. As of current, the exact physical length of the infrastructure is yet to be finalized, considering multiple studies were involved. With an estimated cost of US$80 billion, implementation is expected to proceed in phases, beginning with the Jakarta Bay segment, which is projected to require US$8 to 10 billion and take eight to ten years to complete.

This report sets out a strategic framework to guide the next phase of implementation, grounded in lessons from global, regional, and local case studies. Examples include Japan's Tōhoku sea wall, the Netherlands' Deltawerken, South Korea's Saemangeum sea wall, and Indonesia's very own National Capital Integrated Coastal Development (NCICD) initiative in Jakarta (see Appendix for more information). These case studies illustrate not only the potential of large-scale engineered responses, but also the risks of over-reliance on grey infrastructure without social legitimacy, environmental integration, or adaptive governance.

Leveraging these lessons, this report proposes a three-pronged strategy for the North Java coast:

- **Go Forward:** Construct new seaward infrastructure and reclaimed land in areas with high economic returns;
- **Defend:** Reinforce existing coastlines in dense urban and industrial zones using grey or hybrid systems; and
- **Restructure:** Support managed retreat by relocating high-risk settlements, restoring coastal ecosystems, and developing aquaculture in rural areas.

Recognising the scale and complexity of this agenda, the government has designated the Coordinating Ministry for Infrastructure and Regional Development to spearhead inter-ministerial alignment efforts. A new North Java Sea Wall Authority is also being established to coordinate planning, accelerate delivery, and interface with the private sector and investors. Jakarta's NCICD experience provides a critical starting point, but the vision now extends across the entire North Java coastline.

To move from strategy to implementation, the report makes five priority recommendations:

01 **Act now and plan long:** Initiate quick wins in high-risk, high-readiness zones using digital project planning and an adaptive roadmap that evolves with new data and feedback.

02 **Tailor solutions to local context:** Apply different coastal protection strategies – Go Forward, Defend, or Restructure – based on local risk, land use, and economic importance to optimise value and outcomes.

03 **Build with legitimacy:** Empower the North Java Sea Wall Authority with the clear mandate to coordinate across ministries, resolve delivery bottlenecks, and embed coastal protection within national development goals.

04 **Finance innovatively:** Bundle protection infrastructure with revenue-generating projects (e.g., reclaimed land, special economic zones (SEZs), inland transport corridors) to attract private capital and improve project bankability.

05 **Plan holistically:** Develop a consolidated national coastal protection masterplan that integrates spatial, economic, and environmental planning, anchored in a Special Presidential Regulation to ensure cross-government coordination and foster stronger stakeholder support.

If implemented with vision, coordination, and discipline, the Giant Sea Wall project can transform North Java from a region of compounding risk to one of national resilience—protected, productive, and prepared for a changing climate.

Chapter 1
Introduction

The North Java coastline – spanning the provinces of Banten, Jakarta, West Java, Central Java, and East Java – is increasingly being threatened by the convergence of climate-induced and human-made pressures, such as land subsidence, tidal flooding, sea level rise, and rapid urbanisation. Over the past two decades, the government has initiated several coastal development efforts – most notably the NCICD masterplan for Jakarta and integrated protection plans for Semarang-Demak, Cirebon, and Pekalongan.[1] However, implementation to date has not kept pace with the scale and urgency of the threat .

Recognising these challenges, strengthening climate resilience alongside the nation's economy remains a priority for the Indonesian government, as reflected in the missions of its Asta Cita agenda that are aligned with core objectives of the 2025-2045 National Long-Term Development Plan (RPJPN). Specifically, Asta Cita 2 includes within its scope water, energy, and food security; Asta Cita 5 includes the promotion of environmentally-balanced industrial and maritime development; and Asta Cita 8 covers sustainable growth through flood control and spatial planning.[2] To deliver on these priorities, coastal protection is required as a central pillar of Indonesia's long-term development agenda. In this context, the Giant Sea Wall project has emerged as a national flagship initiative.

Led by the President of Indonesia, and supported by the Coordinating Ministry of Infrastructure and Regional Development, this project is expected to culminate in a 500-to-946-kilometres coastal barrier stretching from Banten to Gresik ,[3,4] designed to safeguard vulnerable communities, protect economic assets, and enable climate-resilient growth along the North Java coastline. The physical length of the infrastructure is provided in ranges considering multiple studies are involved and yet to be finalized. The President announced the sea wall can span from 500 kilometres in June 2025, whereas Ministry of Public Works stated that the sea wall is estimated to span as long as 946 kilometres earlier in March 2025. The cost to build the sea wall can start from US$80 billion. Construction will be conducted in phases, starting with the Jakarta Bay segment which is expected to cost US$8 to 10 billion and take eight to ten years to complete.[5]

To accelerate progress, the government has called for cost-sharing mechanisms to be established between national and provincial governments, and stressed the importance of strong political coordination, regulatory clarity, and long-term financing to ensure continuity over the 15 to 20-year timeline for the construction of the entire Giant Sea Wall.

Most recently in 2025, the President also announced the planned establishment of the North Coast Sea Wall Authority (*Badan Otorita Tanggul Laut Pantai Utara Jawa*) as the dedicated body overseeing this effort.[6] Reporting directly to the President, the agency will oversee integrated planning, financing, stakeholder engagement, and governance for the project in coordination with the Coordinating Ministry for Infrastructure and Regional Development, the Ministry of Public Works, and other relevant ministries.

Purpose of this report

Indonesia's Giant Sea Wall initiative represents a pivotal milestone in its long-term climate adaptation strategy. This report has been developed to support the Government of Indonesia, including the soon-to-be established North Coast Sea Wall Authority, in developing a clear coastal development strategy that is actionable, context-specific, and tailored to the economic drivers of communities along the North Java coastline.

Given the project's scale, complexity, and financial demands, a coordinated and well-informed approach is critical to guide decisions related to design, phasing, financing, and governance. Specifically, this report showcases a comprehensive analysis that includes the following:

- Identification of the array of coastal protection strategies, including where sea wall solutions may be most appropriate and how they can be integrated with nature-based and hybrid approaches;
- Assessment of the benefits, limitations, and trade-offs of different sea wall typologies (offshore, nearshore, and onshore);
- Lessons learned from large-scale national and international sea wall and coastal protection projects; and
- A strategic framework for coastal protection that outlines a tailored implementation approach for North Java, supported by enabling institutional, financial, and policy actions.

The case for coastal protection along the North Java coastline: Why it matters

The North Java coastline, also known as Pantai Utara Jawa or Pantura, is Indonesia's most economically vital corridor, contributing to over 20% of the national GDP.[7] Spanning five provinces, Pantura hosts 70 industrial zones, five SEZs, 28 power plants, and 196 ports – including the key international ports of Tanjung Priok, Tanjung Perak, and Tanjung Emas – which are vital to regional and international trade for the 50 million people residing in Pantura.[8]

However, this region faces an escalating convergence of climate-induced and anthropogenic threats, most notably land subsidence, coastal erosion, and sea level rise. Every year, land subsidence driven largely by excessive groundwater extraction in soft sediment areas varies between 4 and 11 centimetres in Jakarta, Cirebon, Indramayu, Pekalongan, Semarang, Demak, Gresik, and Surabaya (see Figure 1).[9] Some low-lying areas are also prone to coastal erosion (or 'abrasion'), further aggravating flood risks.

The cost of inaction is immense. Without coordinated intervention, nearly 490,000 hectares of land could be impacted, jeopardising the livelihoods of over 160,000 coastal fishers and exposing critical infrastructure to permanent inundation. Potential economic damages have been estimated at around US$1.86 trillion, much of it concentrated in Jakarta.[10]

Figure 1: Land subsidence along the North Java coastline

Source: Center for Groundwater and Environmental Geology and the Ministry of Energy and Mineral Resources of Indonesia.

Current state of coastal resilience efforts in Indonesia

over the past two decades, the Government of Indonesia has taken important steps to strengthen coastal resilience in North Java, starting from Jakarta. In 2009, the Ministry of National Development Planning (Bappenas) introduced the Jakarta Coastal Defence Strategy, which subsequently evolved into the Jakarta Coastal Defence System (JCDS) in 2012, NCICD-I in 2014, and NCICD-II in 2020. The first was developed with support from the government of the Netherlands, with South Korea joining the NCICD-II project in 2018.

The NCICD-II project, in particular, resulted in the development of a sea wall strategy and plan known as the Integrated Flood Safety Plan 2020 (IFSP 2020).[11] Formalised under Ministerial Decree No. 112/2022, the NCICD adopts a three-phased approach (A, B, and C) and includes two sea wall scenarios – open and closed – depending on the severity of land subsidence.[12] This initiative was, in turn, later integrated under the Pantura Java Integrated Coastal Development Plan (PJICDP), a broader program that extends the resilience framework beyond Jakarta to include the wider North Java coastline.

The President has reaffirmed the government's long-term commitment to this renewed agenda, and appointed the Coordinating Ministry of Infrastructure and Regional Development to integrate coastal protection across high-risk areas, such as Semarang, Pekalongan, and Demak. Currently, there are a handful of project-based coastal resilience plans along the North Java coastline that would later need to be consolidated under the Giant Sea Wall project.

Challenges ahead for the Giant Sea Wall

While initial efforts to build coastal resilience in parts of North Java are underway, scaling it into the Giant Sea Wall represents a major leap that comes with significant challenges and considerations. These include the following:

01. Attracting new sources of funding apart from state budgets, against a backdrop of low project bankability related to sea wall development: The Giant Sea Wall is a major investment, with an estimated cost of US$80 billion for the 500 to 946 kilometre-long sea wall (or an average of US$100 million per kilometre).[13,14] Recognising the scale of this undertaking, the Indonesian government has committed to mobilising both public funding and private sector participation. This calls for a project structure that not only advances national resilience goals, but also presents a compelling business case to attract private investment.

02. Building a strong economic, environmental, and social rationale accepted by all stakeholders: The construction of a sea wall will inevitably result in disruptions to coastal ecosystems, and will be met with resistance from coastal communities. A strong environmental and social rationale must therefore be established, supported by a clear cost and benefit analysis. This includes identifying mitigation strategies for potential adverse impacts, and articulating the long-term value that the project can deliver in terms of coastal protection, sustainable livelihoods, economic growth, and ecological resilience.

03. Regulatory and planning alignment across provinces, amidst existing plans and projects across the different coastal regions along the North Java coastline: Currently, coastal protection and development programs are carried out under the authority of different ministries, agencies, and local governments based on sectoral regulations. As the Giant Sea Wall is a project spanning five different provinces, there needs to be a dedicated, overarching law to provide a unifying legal framework. Furthermore, several regions have commenced their own coastal protection and sea wall initiatives that would need to be integrated into the broader Giant Sea Wall plan.

04. Urgency to execute the Giant Sea Wall project without compromising quality: The directive from the President is clear: the Giant Sea Wall project must be executed immediately. This urgency is backed by strong government direction to begin work on the segment of the sea wall located in the northern part of Jakarta, leveraging its strong regional budget to fund the project which has been estimated to cost between US$8 and 10 billion.[15] However, rapid execution without thorough planning increases the risk of long-term failure. Advanced technologies, such as AI for integrated planning, execution, construction, and maintenance can be leveraged to enforce quality standards, and deliver durable outcomes under an accelerated timeline.

In light of these challenges, this report aims to provide a set of actionable recommendations aimed at guiding the Government of Indonesia in addressing the identified issues. Before outlining these next steps, however, we will first examine the broader context of coastal protection, how different strategies can be adapted to fit the unique context of the North Java coastline, and where the Giant Sea Wall fits in within that broader landscape.

Chapter 2
Broad strategies for coastal protection

As Indonesia embarks on its Giant Sea Wall initiative, it is essential to frame this ambition within the broader landscape of coastal protection strategies. While sea walls are a prominent and technically proven intervention, they represent only one option in a diverse set of tools for building coastal resilience. Indeed, different strategies are suited to different contexts.

For example, areas with high-value urban assets may require more engineered defences, while regions with extensive natural coastlines or lower development densities may benefit more from nature-based or restructuring approaches. Effective coastal protection requires a context-specific approach, one that accounts for local geomorphology, hazard exposure, ecological systems, development patterns, and community needs.

This chapter introduces a strategic framework to guide decision-making across three broad approaches:

Go Forward strategies, which expand land and infrastructure seaward through reclamation or offshore structures, are best suited for areas where economic returns from reclaimed land or port expansion justify high capital costs;

Defend strategies, which reinforce the existing coastline using grey or hybrid infrastructure, are more appropriate for the protection of dense urban or industrial areas where restructuring is not feasible; and

Restructure strategies, which are also known as managed retreat, entail relocating at-risk assets and communities inland while restoring coastal ecosystems and developing aquaculture.

We will also present a spectrum of solution types, from traditional grey engineering to green (nature-based) and hybrid (green-grey) interventions, and consider their relative strengths, limitations, and use cases. These solutions will be compared in terms of their costs, co-benefits, implementation complexity, and long-term sustainability. Such an approach emphasises that an integrated coastal strategy must balance physical protection with economic benefits, environmental integrity, long-term maintenance, and community acceptance. A summary matrix is also provided to illustrate the general suitability of these solution types under each strategic approach, helping to guide planners and policymakers in aligning technical choices with broader adaptation pathways.

By outlining these strategic options and solution typologies, this chapter lays the foundation for a more focused discussion on sea wall typologies, benefits, and trade-offs in Chapter 3. It provides the necessary context to evaluate when, where, and how sea wall investments might be appropriate, and how they can be integrated into a holistic, adaptive resilience strategy for the North Java coastline.

Strategies for coastal protection

To guide the selection of the appropriate approaches, it is necessary to compare the key characteristics, advantages, limitations, and typical applications of the three primary coastal protection strategies: Go Forward, Defend, and Restructure (see Table 1). This summary provides a high-level reference point to assess their suitability across the different physical, social, and economic contexts, which we will discuss in greater detail in the sections ahead.

Table 1: Summary of high-level coastal protection strategies

Strategy	Description	Typical context	Key benefits	Key challenges
Go Forward	Expands land or defences seaward through reclamation or offshore structures	High-density urban zones where retreat is not feasible and urban or commercial expansion is viable	• Increases land area • Strong protection of urban assets • Solves urban obstacles and constraints	• High cost • Environmental and social impact • Complex hydrodynamics
Defend	Reinforces existing coastline with engineered or hybrid solutions	Areas with moderate population density and limited urban or commercial expansion pressure, and where the coastline is relatively stable or demonstrates accretional trends	• Maintains existing land use • Phased and adaptive upgrades are possible	• Integrating sea walls in urban areas may be challenging • Ongoing investment in upgrading and maintenance is required
Restructure	Relocates development inland, allowing space for natural buffers and better protection for at-risk settlements	Rural, subsiding, or severely exposed coastlines	• Long-term resilience • Ecological restoration • Lower lifecycle cost	• Social acceptability • Land acquisition • Multi-phase planning

Go Forward

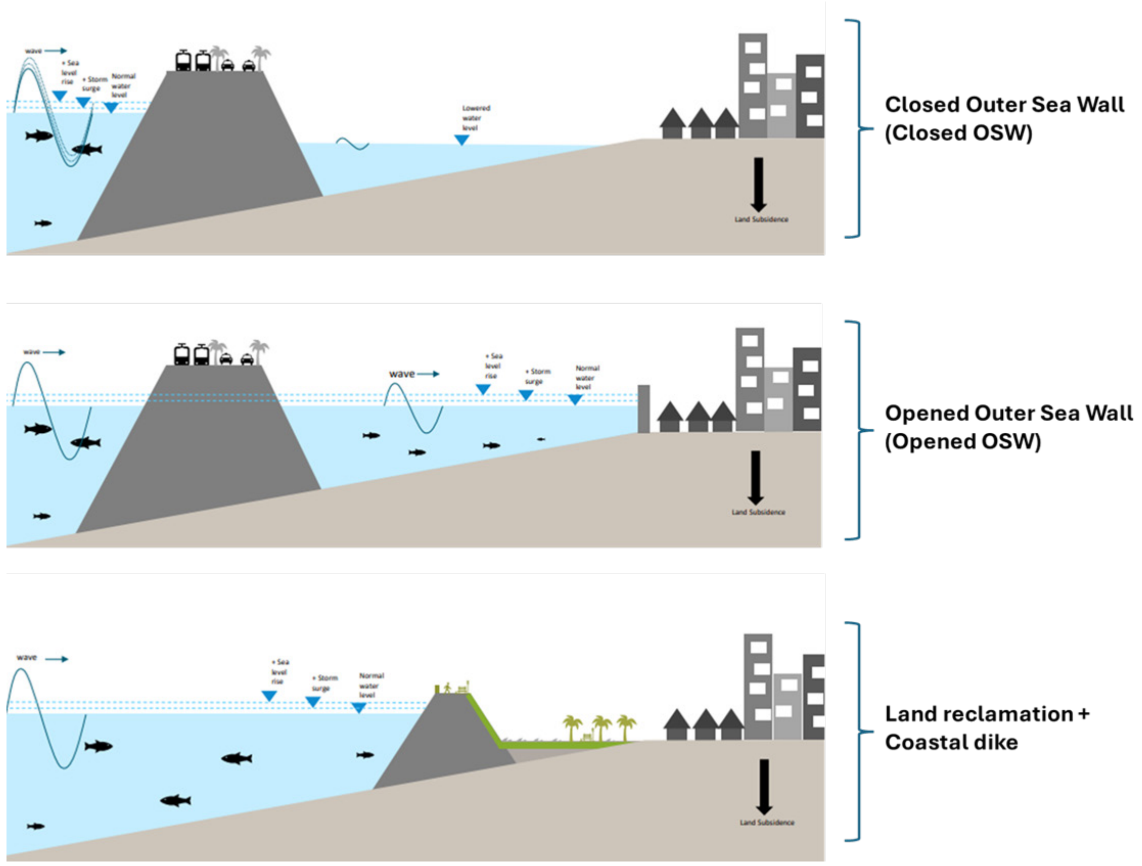
The Go Forward strategy represents a proactive approach to coastal development, where infrastructure and defences are extended toward the sea, instead of retreating or maintaining the current coastline (see Figure 2). Key characteristics of this strategy include:

- Construction of new coastal defences located seaward of the existing coastline, such as offshore sea dykes or sea walls; and
- Land reclamation, where new land is created, or existing coastlines are extended seaward to accommodate urban expansion, commercial development, or strategic infrastructure.

Potential solutions include fully closed and large seaward sea dykes, partially open big seaward sea dykes, and sea dykes at the front of a land reclamation site. This strategy is typically applied in high-density urban coastal zones, where relocating populations inland is not economically or politically viable and pressure on available land is high.

However, while this method can offer increased land and protection, it may also lead to significant environmental impacts, as well as higher construction and maintenance costs and changes to sediment and tidal dynamics. It also requires a careful modelling of regional hydrodynamic effects to avoid unintended consequences, such as wave reflection or erosion of adjacent coastlines.

Figure 2: An illustration of the Go Forward strategy[16]



Source: Haskoning.

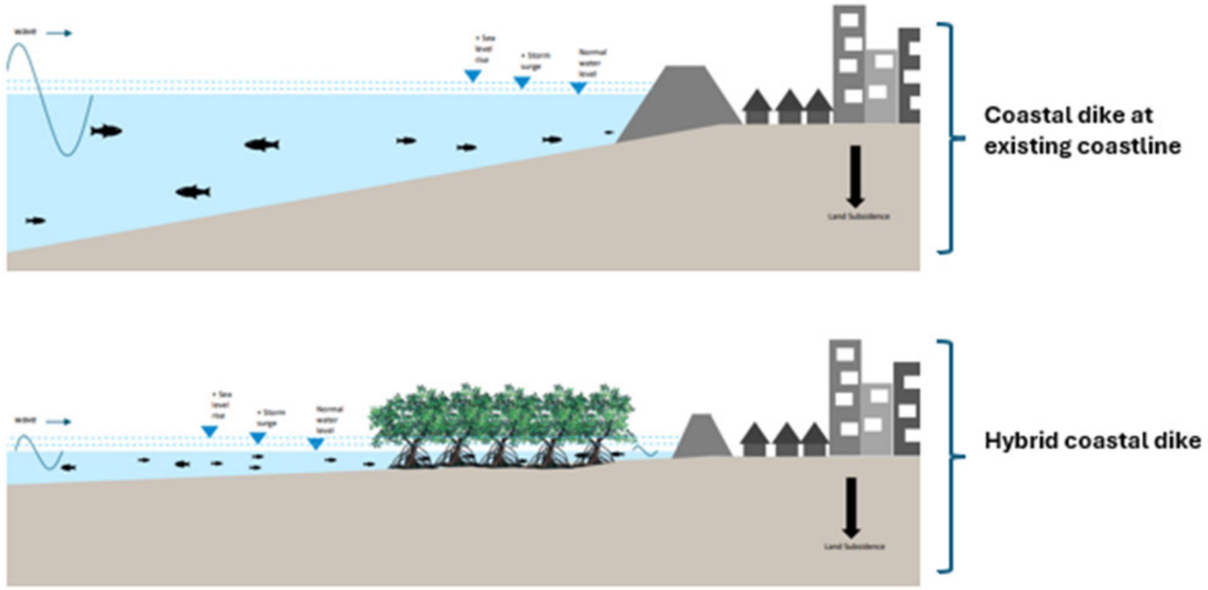
Defend

The Defend strategy focuses on reinforcing and maintaining the current coastline to protect inland areas and existing infrastructure from coastal threats (see Figure 3). Key characteristics of this strategy include:

- Coastal protection located at the current coastline, for example by means of an onshore or near-shore coastal dyke; and
- The use of 'hard' engineering solutions (e.g., sea walls, groynes, breakwaters, and revetments) and 'soft' engineering approaches (e.g., beach nourishment and dune restoration).

Potential solutions include sea dykes at the current coastline or hybrid sea dykes with mangroves in front. This strategy is typically applied in medium densely populated coastal cities with limited urban and economic pressure to develop new land or freshwater reservoirs, and where Go Forward strategies are not economically or environmentally feasible. Defend strategies can be deployed along adaptive pathways, with low-consequence interventions such as beach nourishment transitioning to more robust protection as risks increase.

Figure 3: An illustration of the Defend strategy[17]



Source: Haskoning and Witteveen+Bos.

Restructure

The Restructure strategy, also known as managed retreat, managed realignment, or planned relocation, involves relocating or reorganising coastal settlements and infrastructure further inland. Typically, settlements identified for relocation are those that have become isolated and exposed, and which are situated some distance offshore.

Due to their geographical position, these communities cannot be effectively protected against flooding. Restructuring therefore allows for a more sustainable line of defence and the integration of nature-based solutions, especially in areas where it is no longer viable to defend the existing coastline as a result of subsidence, erosion, or frequent flooding.

It is important to note, however, that this strategy does not imply inaction; on the contrary, it involves carefully planning structural and non-structural measures to realign coastal protection systems with their ecological and socio-economic outcomes.

There are two primary types of restructuring approaches: Coastal Restructure A, which combines nature-based solutions with hybrid infrastructure; and Coastal Restructure B, which focuses on managed relocation and the repurposing of vacated coastal land.

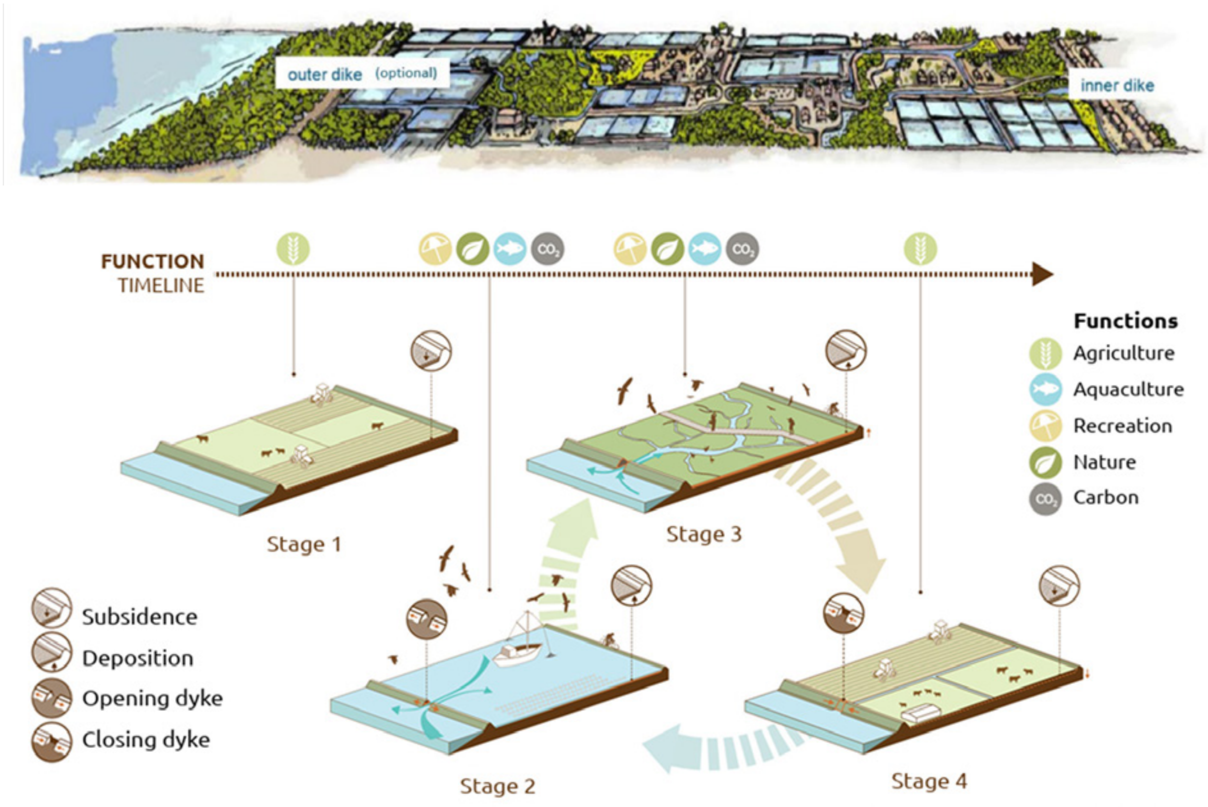
Coastal Restructure A

This approach combines natural features, such as mangroves that act as natural flood buffers by reducing wave energy and trapping sediments, with selective structural interventions to reduce flood risks while supporting ecological health (see Figure 4). It is suitable for coastlines with low population density and stable or growing land areas.

In some cases, offshore dykes can be added for additional protection against severe storm surges. However, in areas designated for aquaculture or fishponds, frequent small floods are considered acceptable, so a sea dyke may be omitted. To protect residential zones and ensure human safety, an inner flood dyke can be constructed inland.

Under this approach, mangrove and wetland restoration and wetland also play a vital role in carbon sequestration by capturing and storing atmospheric carbon dioxide to reduce greenhouse gases and mitigate climate change. These ecological interventions offer dual benefits – enhancing climate resilience whilst strengthening flood protection – and help to strike a balance between ecological preservation and flood protection, tailored to the site's characteristics, including its local geomorphology and livelihoods.

Figure 4: An illustration of the Coastal Restructure A approach[18]



Source: Haskoning and NIOZ Royal Netherlands Institute for Sea Research.

Coastal Restructure B

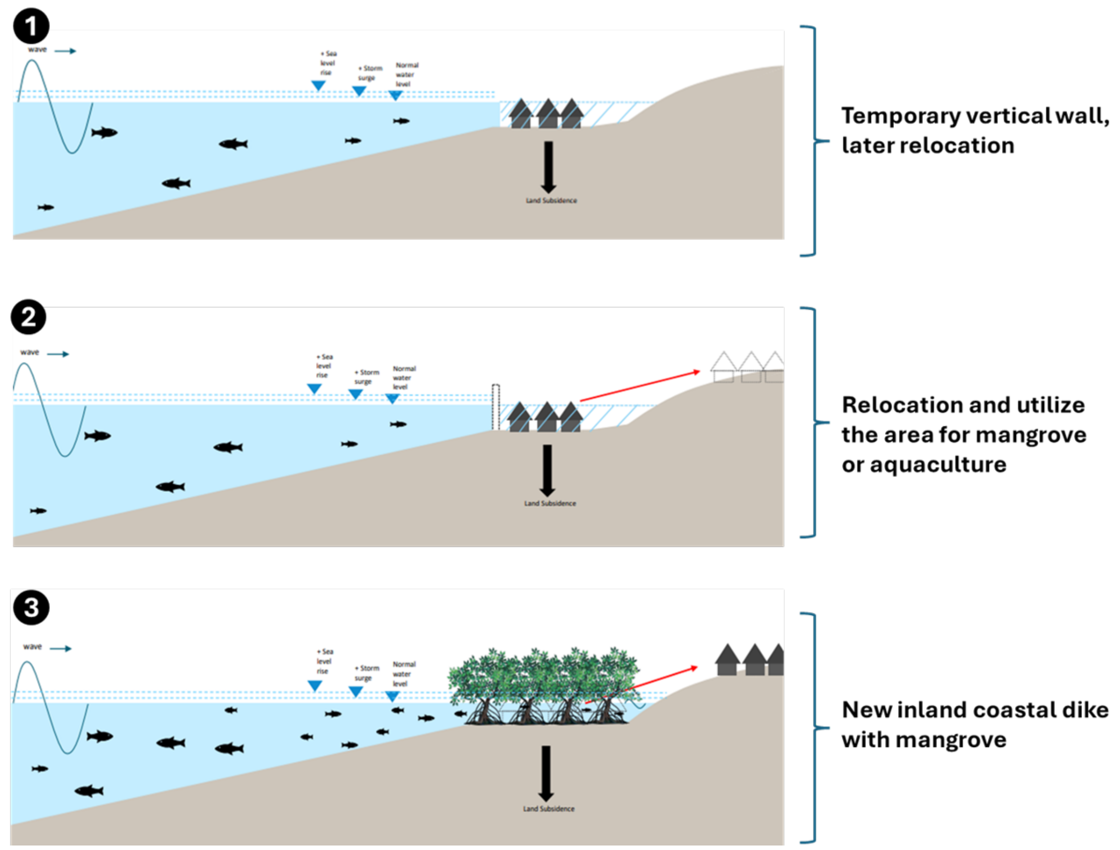
This approach involves relocating residents from highly vulnerable coastal areas and transforming these areas into environmentally or economically productive zones (see Figure 5). It comprises three sub-options, each tailored to different site conditions and community needs:

Option 1: Temporary vertical wall before relocation
A vertical wall is used as an interim flood protection measure during the transition period while the community is being relocated to safer, elevated ground. Temporary floodgates or pumps may be required to manage drainage behind the wall. Following relocation, communities will become safer and long-term defence costs will be minimised. The main challenge, however, lies in gaining community acceptance and cooperation for the relocation.

Option 2: Repurposing a vacated coastal area
Following relocation, the vacated land can be converted into mangrove zones or aquaculture sites to reduce flood risk while delivering environmental and social benefits. This would also help to enhance ecosystem quality, create habitats for marine life, and offer economic opportunities for local communities, such as fishermen.

Option 3: Inland coastal dyke with mangrove foreland
If relocation to higher land is not feasible, an inland dyke can be built. Residents are then moved behind the dyke, and mangroves are planted in its front. A pumping station may be required if the land behind the dyke lies below sea level. Such a combination of a physical barrier and an ecological buffer helps to ensure protection while supporting biodiversity and reducing abrasion, offering a practical compromise where full retreat is not viable.

Figure 5: An illustration of the Coastal Restructure B approach[19]



Source: Haskoning and WitteVeen+Bos.

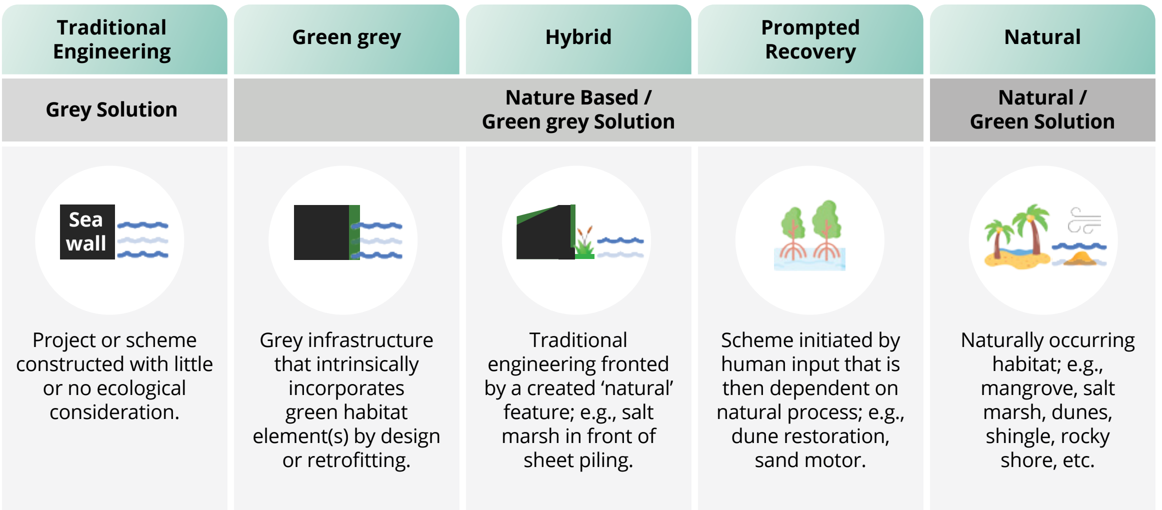
Ultimately, areas experiencing severe subsidence and abrasion may find that traditional flood protection measures are becoming increasingly unsustainable. The strategic relocation of vulnerable communities inland offers a long-term, cost-effective alternative, despite its potential for social resistance.

Unlike a 'do nothing' scenario, this approach leverages both structural and non-structural interventions to enable a phased, managed retreat. While complex, it allows for gradual implementation, minimises disruption, and ultimately ensures a more resilient coastal defence.

Types of coastal protection solutions

All three strategies – Go Forward, Defend, and Restructure – can be realised with a range of solution types: grey (engineered), green (nature-based), or hybrid (green-grey) (see Figure 6). While any strategy can incorporate nature-based solutions, green and hybrid approaches are particularly well suited to Defend and Restructure strategies, where ecological conditions and land use patterns allow for softer interventions. In contrast, Go Forward options often involve deeper water environments and large-scale land reclamation, where nature-based applications are generally more limited.

Figure 6: Different types of coastal protection solutions



In this section, we outline the characteristics, strengths, and trade-offs of each solution type to support practical decision-making and enable the matching of solution types to different coastal contexts (see Table 2):

Table 2: Key characteristics of the different coastal protection solution types

Solution type	Description	Co-benefits	Typical applications	Limitations
Grey	Engineered structures, such as sea walls, dykes, groynes, and revetments	High reliability and predictable performance	Urban/commercial areas requiring strong, immediate protection	• High capital and/or maintenance cost • Low ecological value
Green	Nature-based solutions, such as mangroves, dunes, wetlands, and reefs	Ecosystem restoration and biodiversity; carbon storage; and livelihood support	Low-energy coastlines; and rural or mixed-use zones	• Slower to mature • Dependent on site condition • Ineffective in areas with high subsidence, wave energy, or limited sediment supply
Hybrid (Green-Grey)	Combination of engineered structures with natural buffers or habitats	Multiple lines of defence; reduced maintenance; and enhanced resilience	Sites prioritising both high protection and environmental outcomes	• More complex design and coordination • Still emerging in practice

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Grey solutions

Grey solutions refer to protective measures that rely on traditional engineering and structural approaches to manage coastal risks. These solutions are typically constructed with conventional materials such as concrete, steel, rocks, sand, and clay, and are specifically designed to offer immediate and robust protection against coastal hazards such as storm surges, erosion, and sea-level rise. Common examples include sea walls, bulkheads, breakwaters, groynes, revetments, and storm surge barriers.

One of the primary advantages of grey infrastructure is its high level of predictability and consistent performance, which makes it a preferred option for areas requiring strong and reliable defences. However, these solutions often demand substantial upfront capital investment and ongoing maintenance to ensure their long-term functionality. Additionally, while effective in mitigating physical threats, grey solutions can disrupt natural coastal processes and may result in adverse impacts on surrounding ecosystems, including altering sediment transport, impeding marine biodiversity, and reducing the resilience of coastal habitats. They may also underperform under compound hazards (e.g., when sea level rise is combined with storms and land subsidence) if not regularly upgraded.

Green solutions

Green solutions, also referred to as natural or nature-based solutions, utilise ecological processes and habitats to provide coastal protection while delivering a range of co-benefits. These approaches include interventions such as beach nourishment, dune restoration, wetland creation, mangrove planting, and coral reef restoration. In addition to mitigating coastal hazards, they offer multiple ecosystem benefits, such as enhancing biodiversity, supporting fisheries, sequestering carbon, and improving water quality.

Ideally, green solutions should be self-maintaining and potentially self-adapting, allowing them to respond to evolving environmental conditions such as rising sea levels and increased storm frequencies. As compared to traditional grey infrastructure, green solutions often require a lower initial investment, and could prove to be more cost-effective over the long-term, especially when effectively implemented to harness natural processes.

Nevertheless, the success of nature-based solutions depends heavily on local conditions, including having adequate sediment supply, appropriate salinity levels, and sufficient time for the system to mature. These solutions are typically vulnerable to disturbance during their initial establishment phase but become significantly more resilient once fully developed. They include naturally occurring coastal habitats, such as mangroves, salt marshes, dunes, shingle beaches, and rocky shores, which serve not only as buffers against storm surges but also critical components of resilient and sustainable coastal ecosystems.

Hybrid (green-grey) solutions

Hybrid or green-grey solutions combine nature-based features with conventional grey infrastructure to provide robust, adaptive coastal protection. By deliberately integrating natural systems, such as mangroves, dunes, or wetlands, with engineered structures like sea walls or revetments, these approaches seek to leverage the strengths of both: the reliability and predictability of engineering, and the flexibility and regenerative capacity of natural ecosystems.

There are several forms of hybrid solutions. Some are designed with natural features embedded within the grey infrastructure – for example, vegetated revetments or green embankments. Others consist of grey structures constructed behind restored or newly created ecological buffers, such as mangrove greenbelts or coastal wetlands, which absorb wave energy before it reaches the wall or dyke. In some cases, 'prompted recovery' techniques are used, where engineered interventions such as sediment traps or fencing are used to support the natural regeneration of dunes or mangroves, creating a semi-natural line of defence that evolves over time.

The core advantage of hybrid systems lies in their ability to provide multiple lines of defence. While grey components offer immediate, high-certainty protection, green elements bring long-term adaptability, ecological value, and lower lifecycle costs. Once established, natural buffers can reduce maintenance demands on engineered structures by attenuating waves and trapping sediment.

Importantly, hybrid solutions are often more resilient to climate change than singular grey or green approaches. In addition to reducing flood and erosion risks, they offer broader benefits by restoring habitats, enhancing biodiversity, improving aesthetics and recreation, and supporting sustainable livelihoods. This makes them particularly well suited to sites where both engineering performance and ecological integrity are priorities.

The philosophy of nature-based solutions

The nature-based approach to coastal protection represents a management philosophy that prioritises working with natural processes rather than opposing them. It adopts a holistic perspective of coastal zones as dynamic, interconnected systems that require long-term thinking about sustainability and adaptation to changing environmental conditions.

Instead of imposing rigid engineered solutions, nature-based approaches emphasise minimal intervention and the enhancement of existing natural features, incorporating local knowledge and contextual understanding of coastal ecosystems into decision-making processes. Ultimately, it seeks balanced solutions that simultaneously benefit human communities and natural environments, creating resilient coastlines that can adapt to climate change while supporting biodiversity and sustainable development.

Aligning strategies and solutions for effective coastal protection

While grey, green, and hybrid solutions each have distinct strengths and limitations, their suitability also depends on their alignment with the broader strategic approach adopted – that is whether Go Forward, Defend, or Restructure strategies are chosen (see Table 3). Nevertheless, this alignment only reflects general applicability based on technical feasibility, ecological fit, and socio-economic considerations; in practice, site-specific conditions may require blended approaches or adaptive phasing over time.

Table 3: Indicative suitability of solution types for different strategic approaches

Solution type/ Strategy	Go Forward	Defend	Restructure
Grey	✓✓✓	✓✓✓	✓
Green	×	✓✓	✓✓✓
Hybrid	✓	✓✓✓	✓✓✓

✓✓✓ = High suitability
✓✓ = Moderate suitability
✓ = Limited suitability
× = Not typically applicable

Chapter 3
Sea walls: Typologies, trade-offs, and financing considerations

Building on the strategic coastal protection frameworks introduced in Chapter 2, this chapter takes a closer look at sea walls as one possible component within a broader resilience strategy. While sea walls are amongst the most visible and technically robust forms of protection, they also carry high costs, complex trade-offs, and diverse implementation challenges.

This chapter critically examines the role of sea walls through multiple lenses: their engineering typologies, benefits, and limitations; the socio-economic and environmental impacts of different configurations; and the financing models required to make them viable. It recognises that sea walls can play an important role in highly urbanised and high-risk areas, but only when their design and deployment are carefully matched to local conditions, integrated with other adaptation strategies, and supported by sustainable funding and governance arrangements.

This chapter aims to enhance strategic planning by differentiating sea wall typologies and clarifying their appropriate contexts. It promotes a nuanced, context-sensitive approach to infrastructure that complements Indonesia's broader coastal adaptation efforts, rather than overshadowing them.

Sea wall types and their contextual usage
Sea walls can be broadly categorised into three types – offshore, nearshore, and onshore – each with distinct design considerations, opportunities, and constraints that depend on their physical, urban, and institutional contexts.

Offshore sea walls
Offshore sea walls are big, solid sea walls that are positioned in deeper water (10-25 metres depth), and therefore require a wider footprint for their construction.

Benefits

01. Design and maintenance: Positioning sea walls offshore allows for a more straightforward construction and maintenance process, as they are less constrained by existing urban infrastructure. This separation from densely populated areas reduces the complexity and costs associated with integrating new structures into established cityscapes. For instance, the NCICD sea wall was designed with a lifetime of 75 years, while existing 'urban' sea walls require an upgrade every 10-15 years. Theoretically, existing sea walls on the coastline could also be constructed with a lifetime of 75 years; however, the associated heights above sea level and dimensions (up to 100 metres wide) of such sea walls located next to houses and roads could create major urban disruption both during and after their construction. Major works in a 'obstruction-free' offshore environment are therefore easier to construct and maintain, with less disturbance to urban life. They also avoid the need to relocate residents or businesses and reduce the corresponding impact on daily city operations.

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02. New road or railroad corridors: Offshore sea walls can serve as foundations for new roads or railways, enhancing transportation networks. The planned segment of the Giant Sea Wall in Jakarta includes provisions for toll roads and rail lines atop the structure that aim to improve connectivity, in line with the Decree of the Minister of Public Works and Public Housing No. 112/KPTS/M/2022. Infrastructure networks should be guided by logistical relevance and economic demand, as not every toll road or railway automatically adds value. In Jakarta, a toll road and/or railroad from Tanjung Priok Port to West and East Java would be a useful addition to the existing network, and could help relieve pressures on the existing road network. However, this is not the case along other parts of the Java coastline. An offshore road stretching from west to east may not be justifiable from an economic and logistics perspective as it would compete with the existing Pantura toll road. Additionally, the alignment of such a new offshore toll road would not make sense in some parts of Java as it is located far from urban and economic centre – for instance, in areas such as Indramayu and Jepara where the promontory stretches far into the Java Sea.

03. Freshwater reservoirs for drinking water: Enclosed areas behind offshore sea walls can be developed into freshwater reservoirs, providing a vital source of drinking water. The Giant Sea Wall project envisions transforming Jakarta Bay into such a reservoir to supply the city's water needs. The water quality of such a freshwater body may be poor to moderate, as drains, canals, and rivers will carry pollutants into the body; nevertheless, even polluted water can be used as a source of drinking water, albeit at higher treatment costs, as is currently done for polluted river water. Nonetheless, water quality in the Jakarta Bay might become a concern if river water is not treated before entering the bay.

04. Gentle water conditions for land reclamation: Offshore sea walls can create sheltered water conditions that are highly suitable for land reclamation. For example, the Saemangeum Sea wall in South Korea established a calm, enclosed area that made it feasible to reclaim large tracts of land for agriculture and industrial development. In contrast, reclamation in Jakarta Bay today requires raising the elevation of new land and constructing robust sea defences to withstand tides and storm surges. However, if Jakarta Bay were to be enclosed by a sea wall and effectively transformed into an inland water body with regulated water levels – thereby allowing water heights to be kept consistently low – these protective requirements could be significantly reduced. This approach could lower reclamation costs and make new real estate development more affordable. Pursuing such a controlled system may therefore offer a more efficient and economically viable alternative to conventional reclamation methods.

Challenges

01. Loss of marine ecosystem: Constructing offshore sea walls can cause severe disruption to marine habitats, often leading to the complete collapse of existing saltwater habitats. In many cases, the transformation of coastal bays from saltwater to freshwater environments render the original ecosystem unsustainable. The alteration of natural water flows and sediment patterns can negatively impact coral reefs, mangroves, and other critical ecosystems as it disrupts the delicate balance they depend on. Coastal areas, which serve as critical spawning and nursery grounds for countless marine species, may experience irreversible biodiversity loss, with cascading effects reaching far beyond the project area. Mitigation requires a careful and tailored design that evaluates both socio-economic and environmental impacts. This includes assessing whether the creation of a freshwater reservoir is ecologically viable and beneficial, particularly if water supply exceeds long-term demand, and if any alternative solutions exist.

02. Impacts on fisheries and coastal communities: Changes in marine environments due to sea walls can adversely affect local fisheries by diminishing saltwater fish stocks and impacting the livelihoods of coastal communities reliant on fishing and seafood harvesting in coastal areas and mangroves. The distance that needs to be travelled to reach the open sea will increase, and the sea wall would need to be traversable for fishermen to make this possible. To mitigate this, sea wall designs must consider community access and local fishing routes, embedding socio-economic planning into infrastructure design to ensure continued livelihoods and reduce the burden on small-scale fishers.

03. Port and harbour operations: Sea walls can hinder sea shipping operations, potentially disrupting local economies and trade routes. Ship locks must be constructed to allow for access, but this could lead to hours of waiting time. Logistics planners should weigh these impacts carefully to ensure that key ports remain functional and connected to inland and offshore transport networks. Such infrastructure should only be pursued where it complements, rather than competes, with existing port systems and supply chains.

04. Poor freshwater quality: Water bodies enclosed behind sea walls may experience poor water quality due to limited circulation, leading to issues such as eutrophication and pollution accumulation. Conversion into a well-functioning freshwater body will take many years, and the quality and diversity will not be the same as a seawater coastal system. While polluted, this water can still be used as a source of drinking water, which may be a significant benefit given water scarcity issues related to climate change. Nevertheless, freshwater conversion should only be pursued when water demand projections justify this intervention, and it is ascertained that the body will be able to serve as a reliable and strategic water supply source in the long run.

05. Need for drainage and pumping infrastructure: When rivers and drains enter a reservoir, the water flow must be managed either by gates (when the inside water level is higher than sea level) or pumps (when the sea level is higher than the inside water level). To manage water levels and prevent flooding, extensive drainage and pumping infrastructure is required, adding to the complexity and cost of sea wall projects. The order of magnitude for Jakarta Bay is a series of pumping stations with a maximum capacity of 500-600 m^3 per second. This maximum capacity is mainly required for flood situations, when the influx of river water far exceeds the evaporation of lake water and intake of drinking water. For comparison, the capacity of 500 m^3 per second is twice the pumping capacity of the Afsluitdijk in the Netherlands, which is one of the largest in Europe.

06. No commercial business case: Sea walls constructed solely for flood protection may lack a sustainable business model unless integrated with other revenue-generating developments, such as residential or commercial projects. Public-private partnerships (PPP) schemes for 'dyke only' concepts are highly unlikely as there are no revenues to be expected. A toll road might be able to finance the maintenance of an offshore sea wall, but not the construction of it. Hence, the design of such a structure must go beyond flood defence, and should be envisioned as part of a broader coastal transformation initiative. This includes combining sea wall infrastructure with urban development, logistics infrastructure, and resource management plans to generate returns and ensure sustainability.

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Variations

Offshore sea walls and their associated works – such as reservoirs, toll roads, reclamations – can be designed in many ways, depending on their specific context and socio-economic goals. For instance:

01. Reservoirs can be flushed by either seawater (by creating a permeable, closable sea wall) or river water (flushing during the rainy season when water is less polluted) to improve water quality;

02. Rivers can either be connected to the reservoir to provide more fresh water, or directly discharged into the sea, which requires less pumping and prevents severely polluted rivers from affecting the quality of the reservoir;

03. Reservoir levels can be managed depending on goals – for example, maintaining high water levels when the reservoir is a source of water supply, or maintaining low water levels when the reservoir is used for floodwater retention and land reclamation;

04. Access to sea can be arranged either via ship locks or bridges and tunnels;

05. Green-grey options, such as the integration of mangroves in sea walls, can be leveraged to offer attractive ecological opportunities while also contributing to flood defences.

Nearshore sea walls

Nearshore sea walls are built in shallow waters, not too far from the existing coastline. Such a location allows for easier construction without the interference of urban infrastructure, and the space between the sea wall and the original shoreline is often filled with sand. Examples of nearshore sea walls can be found in Jakarta, in areas such as Pluit and Kalibaru.

Benefits

01. No urban constraints: As near-shore dykes are built at some distance (50-200 metres) from the existing coastline, no urban constraints are present, allowing relatively easy construction.

02. Local socio-economic benefits: The area between the dykes and existing land can be reclaimed and used for housing, commercial, and industrial purposes; however, benefits will be limited to the size of the works. Most of these benefits will also be local and community-based – for example, in the form of additional space for recreation and small businesses.

03. Community acceptance and positive perception: As the direct beneficiaries are residents, nearshore sea walls often gain support from local communities. Smaller reclamations tend to bring benefits that are more visible and relatable to local communities, unlike larger offshore mega-projects that may appear disconnected from local priorities.

04. Moderate capital expenditure requirements: Construction in shallow waters requires less material volume compared to offshore projects. The scale of the works is relatively smaller, making the overall investment more manageable. Furthermore, relative to large-scale offshore sea walls, these nearshore alternatives offer a more cost-effective solution for coastal protection with moderate infrastructure needs.

Challenges

01. Financing: As the benefits and opportunities are mostly local, revenues will be limited. This reduces the attractiveness of these works for investors. Unlike large sea walls with large reclamations that are more attractive to investors, such reclamations are more likely to be developed and managed by state-owned investors.

02. Limited scale of socio-economic opportunities: Nearshore sea walls do not offer space for more ambitious socio-economic plans, such as the creation of large water reservoirs, regional or national toll roads, or expansion of cities. The benefits and opportunities are mostly local.

Variations

While structural variations in the sea wall are limited, the reclaimed area between the sea wall and original shoreline can be adapted to serve local needs. Depending on the specific site and urban demand, this space can be developed into housing clusters, recreational green belts, markets, or small-scale infrastructure, adding functional value without requiring large-scale investment or transformation.

Onshore sea walls

Onshore sea walls are mostly either made with concrete sheet or spun piles. They are often narrow, which is a bonus in dense urban areas. Despite their widespread use, however, onshore sea walls present a unique set of advantages and limitations that influence their effectiveness as coastal protection measures.

Benefits

01. **Conventional construction:** Most onshore sea walls are only a few metres high and can be constructed by local firms using conventional materials and techniques, such as sheet piles and poured concrete, allowing for relatively straightforward project execution without the need for specialised machinery or expertise. However, poor construction is also often an issue as procurement tends to focus on securing the lowest cost supplier.

02. **Rapid construction:** Conventional construction also allows for more rapid construction and upgrade of existing sea walls. As the materials and methods are standard and readily available, and no mobilisation of specialised equipment is required, projects can proceed without lengthy preparation or specialised workforce training.

03. **Low capital expenditure:** Onshore sea walls are generally low-cost solutions due to their use of conventional materials and local, low-cost companies. The use of local materials and labour, combined with straightforward construction methods, results in greater affordability compared to offshore or nearshore sea walls. Procurement based on the lowest bid can further reduce costs, although this comes with risks.

04. **Narrow footprint:** Onshore sea walls often have a narrow structural footprint, which is beneficial in densely populated coastal areas with limited space. Their compact design allows for installation without requiring extensive land reclamation or the displacement of existing urban infrastructure.

Challenges

01. **Structural vulnerability and risk of collapse:** High, narrow sea walls built with sheet piles or poured concrete are prone to collapse and structural failure, especially in soft clays present in many coastal areas. It is not the preferred method when sea water is several metres above street level, as the water and wave pressure on such a sea wall will be high. The prevalent procurement strategy focusing on securing the lowest cost bidder tends to promote the use of cheaper materials and less robust construction practices, increasing the risk of collapse and long-term durability issues.

02. **Urban disruption:** Coastal zones tend to be densely populated in the case of cities, or used for agriculture and aquaculture in more rural areas. Houses are often located next to sea walls, or even built on top of them. Repair or upgrading efforts may require the temporary relocation of residents and disruption to daily urban activities, which will complicate project logistics and increase social costs. Inspection, repairs, and upgrades are also often difficult and involve relocation.

03. **Leakage and water pressure issues:** Sea water pressure on onshore sea walls can result in leakage through or beneath the structure. This not only causes nuisance and damage to adjacent properties, but also compromises the integrity of the wall itself, reducing its effectiveness and lifespan.

04. **Limited socio-economic benefits:** Onshore sea walls primarily serve as narrow flood barriers without integrated socio-economic functionalities. They are narrow, high walls without any other benefits for communities other than flood protection. Furthermore, they often act as physical barriers limiting coastal access, forcing communities to build stairs or jetties to maintain connectivity with the sea.

05. **Encroachment and access issues:** Communities living near onshore sea walls may eventually use the structures for informal development, such as building homes, jetties, or other facilities on or adjacent to the walls. This encroachment obstructs inspection, maintenance, and repair activities, potentially jeopardising the wall's effectiveness over time.

06. **Subsidence impact:** In heavily subsidised areas such as Semarang and Demak, land levels can drop significantly (up to 10 centimetres per year), causing the sea wall crest to subside with the ground. Over 10 to 20 years, this could reduce the height of the sea wall relative to sea level by one to two metres, severely undermining its protective function.

Variations

Variations in onshore sea walls are primarily related to construction methods (e.g., sheet piles, blocks, poured concrete) and shapes. While these sea walls do offer some local socio-economic opportunities – such as the incorporation of boardwalks or promenades to improve public spaces and community engagement, small jetties for local fishermen to maintain access to the sea, or construction of roads or pedestrian paths atop sea walls to improve urban connectivity – the scale of benefits remains limited compared to offshore sea walls or integrated coastal development projects.

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Summary comparison of sea wall types

Each of the three sea wall types – offshore, nearshore, and onshore – come with their own set of technical, environmental, and socio-economic dimensions (see Table 4). Comparing them along these dimensions can help us to identify the contexts in which each type is most suitable, and highlight the trade-offs involved in selecting one over another.

Table 4: Comparative overview of the three sea wall types

Sea wall type	Suitable locations	Construction complexity	Socio-economic benefits	Environmental impact	Long-term viability	Capital expenditure requirements
Offshore	Urban coastlines with space and resources	High	High (transport, water, land development)	High	High	High
Nearshore	Densely built coastlines with some setback	Moderate	Moderate (local improvements)	Moderate	Moderate	Medium
Onshore	Highly urbanised edges with limited land	Low	Low (limited to protection)	Low to moderate	Low (especially in subsidence areas)	Low

Financing considerations for sea wall development

Sea wall solutions vary widely in scale, complexity, and the co-benefits they offer. These differences have direct implications on how they are financed. Offshore sea walls, for example, may justify large investments when integrated with roads, ports, or urban development, while smaller onshore walls tend to rely solely on public budgets.

Yet, across all types, financing remains a core challenge. These are capital-intensive assets with limited revenue potential, often entangled in complex permitting and social safeguards and falling outside conventional infrastructure finance models.

This section explores the financing landscape for sea walls, highlighting the conditions under which public, private, and blended approaches become viable, and the strategic considerations needed to match project type with appropriate funding pathways.

Core financing challenges

Despite their critical role in climate resilience, sea wall projects face structural financing constraints that limit their scalability and bankability. These challenges apply across all typologies but are especially pronounced for large-scale, offshore interventions:

- **High capital expenditure, low revenue:** Sea walls, especially offshore structures, require major capital investment and hence cannot solely rely on state budgets. However, they do not typically generate direct cash flows, rendering them unattractive to private investors.
- **Unfavourable investment conditions:** In the case of Jakarta's NCICD, investors were required to pay substantial annual contribution fees (starting at 1% of the reclaimed land value and increasing by 4% per year over five years) to offset marine and coastal ecosystem impacts.[20] While these provisions were designed to address environmental considerations, feedback from market participants suggests that the resulting cost structure might have diminished its overall investment attractiveness. Such conditions are more readily manageable for investors with substantial financial capacity and long-term development portfolios, which could potentially limit the diversity of private sector involvement in similar large-scale projects .
- **Social and environmental hurdles:** Projects that alter coastal ecosystems often face regulatory hurdles, lengthy consultations, and social opposition, adding to their risk and uncertainty.

Financing models by typology

The viability of different financing approaches depends heavily on the type of sea wall being proposed. Each typology carries distinct cost profiles, risk levels, and co-benefit potential, which shape its suitability for public, private, or blended funding (see Table 5).

Table 5: Indicative financing models and characteristics by sea wall typology

Sea wall type	Typical funding source	Financing characteristics	Financing strengths
Offshore	PPPs, public grants, and international financial institutions (IFI) loans	Bundled with high-value assets, and requires strong enabling environment	Value capture via roads, ports, or land; IFI interest high
Nearshore	Public investment, and local development funds	Modest co-benefits, and often led by local State-Owned Enterprise (SOEs) (e.g., local water utilities, port authorities, or coastal development agencies)	Strong community support; fits municipal planning
Onshore	National or municipal budgets	Low-cost, limited function, and public funding only	Rapid deployment; emergency response tool

Unlocking investment: emerging instruments

While traditional public funding remains essential, a range of innovative financing tools can also be leveraged to unlock additional capital for sea wall projects, especially those offering broader resilience or development benefits. These instruments aim to overcome core financing barriers by reducing investor risk, improving project bankability, and linking financial returns to climate adaptation outcomes. Key approaches include:

- **Blended finance,** which combines concessional capital from development banks or donors (e.g., grants, guarantees) with commercial investment to de-risk coastal resilience projects
  Example: *The Global Fund for Coral Reefs (GFCR) blends grants backed by the United Nations (UN) and concessional finance with private-sector-led equity funding, managed by an investment manager.*[21]
- **Climate adaptation funds,** which are direct grants from international sources (e.g., United Nations Development Programme (UNDP), Green Climate Fund) for non-commercial resilience works
  Example: *Tuvalu's Coastal Adaptation Project is financed by a US$36 million Green Climate Fund grant, spotlighting viability for small-scale coastal infrastructure.*[22]
- **Resilience bonds,** which are debt instruments whose yields depend on the achievement of agreed resilience outcomes to incentivise investor monitoring and ensure accountability.
  Example: *The Fiji 'Blue Bonds' are structured to mobilise investment from local banks, financial institutions, and international investors in the blue economy. Beyond showcasing bonds as an innovative tool for financing for ocean sustainability, these initiatives exemplify blended finance by leveraging UNDP's Blue Accelerator Grant Scheme (BAGS) to support capacity building and de-risk locally developed blue economy projects, transforming them into investable businesses.*[23]
- **Revenue bundling and PPP models,** where sea walls are co-developed with productive assets such as toll roads, port access, or reclamation to generate revenue streams that support financing.
  Example: *The Coastal Road Project in Mumbai, India integrates sea wall construction for coastal protection with more bankable components such as a toll road, land reclamation, and a public promenade. Phase I, which included the sea wall, began operations in March 2024.*[24] *A similar bundling is also recommended in Jakarta's NCICD, through the integration of outer sea walls with toll roads, reclamation, and urban land development within a PPP framework to unlock private and international funding.*[25]

Strategic considerations

Sea wall financing must be approached as part of a wider coastal development strategy, not as standalone infrastructure. Financing success is more likely when sea walls are embedded within integrated urban-coastal development strategies. Key enablers include:

- Clear linkage of sea wall benefits to broader economic or social returns (e.g., urban expansion, water security), and existing urban plans;
- Ability to harness land value capture, user fees, or tourism revenues to sustain operation and maintenance (O&M) costs; and
- Institutional coordination to align urban, coastal, and financial planning bodies from the outset.

In short, the financial viability of sea wall investments is closely tied to their ability to deliver multiple benefits. Projects that integrate flood protection with development value are more likely to attract sustained support, funding, and political commitment.

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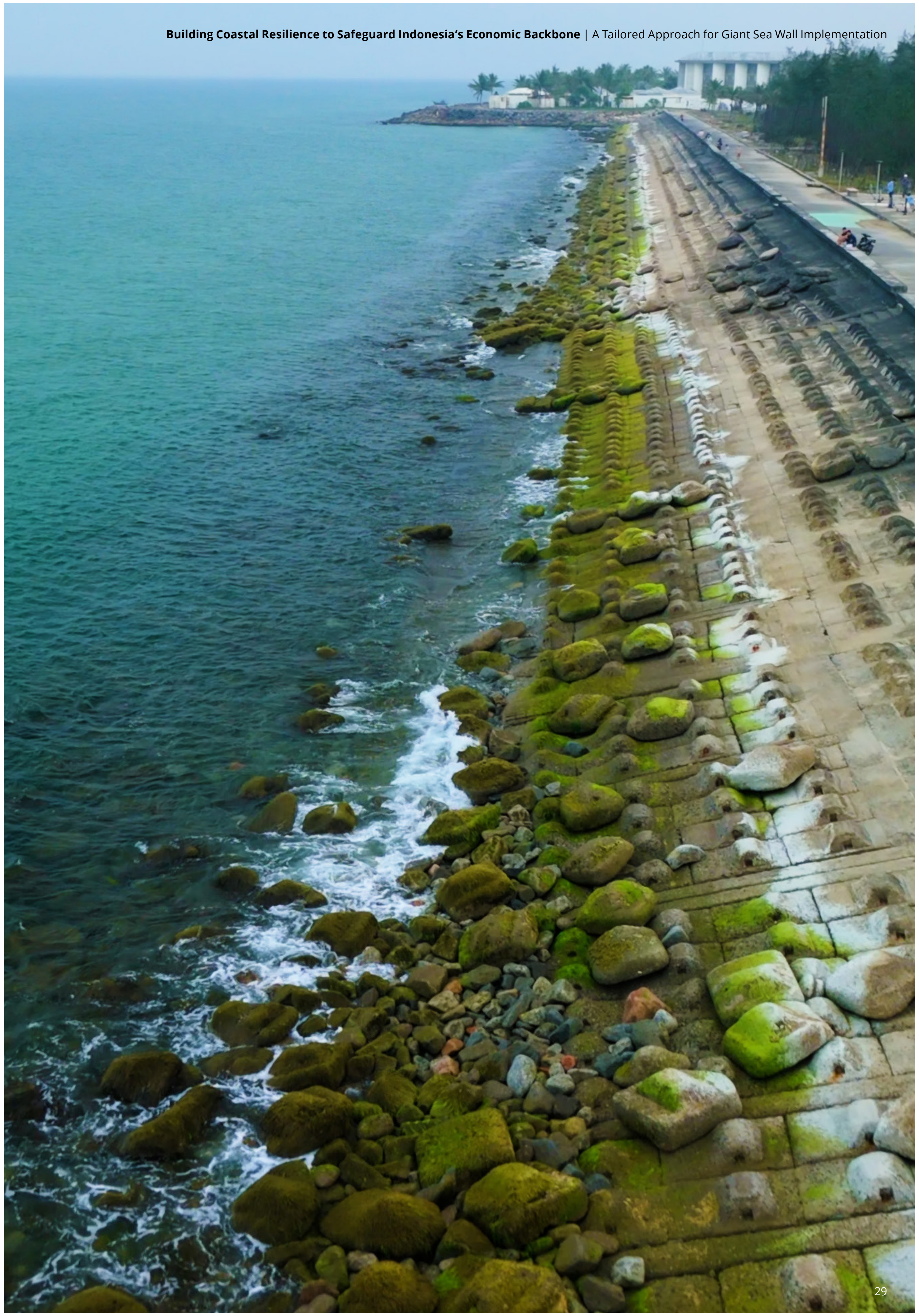

Chapter 4
Global case studies and lessons learned

Around the world, several markets have implemented large-scale sea wall systems – some successfully, others with challenges. These experiences offer valuable insights into how such complex infrastructure can be planned, financed, and governed over time.

This chapter focuses on case studies and lessons learned about a specific category of sea walls – specifically giant sea walls, defined by their exceptional length (10 kilometres or more), multi-billion-dollar investment scale, and multifunctional purpose.

While not a formal classification, this practical lens helps distinguish globally significant projects that combine engineering ambition with complex urban, social, and environmental objectives. We will review five major global case studies that meet these criteria:

01. Tōhoku sea wall in Japan, built after the 2011 tsunami to protect over 400 kilometres of coastline;[26]

02. Afsluitdijk in the Netherlands, a landmark example of flood protection integrated with land reclamation, ecological engineering, and adaptive governance;[27]

03. Deltawerken in the Netherlands, an extensive system of dams, sluices, locks, dykes, and storm surge barriers designed after the 1953 North Sea flood to protect low-lying regions from future storm surges;[28]

04. Saemangeum sea wall in South Korea, which combines coastal defence with water management, energy production, and large-scale land reclamation;[29] and

05. Sihwa Tidal Power Plant in South Korea, the world's largest tidal power station, developed by converting a former saltwater bay into a tidal reservoir through a 12.7-kilometre sea wall.[30]

These projects offer valuable insights, not only into the technical and financial dimensions of sea wall construction, but also the trade-offs in terms of environmental impacts, social acceptance, institutional complexity, and long-term maintenance requirements. Understanding what worked, and what did not, in these international examples is critical as Indonesia embarks on its Giant Sea Wall initiative. Each case presents a different model of navigating complexity, aligning stakeholders, managing risks, and delivering durable value across multiple objectives.

This chapter includes a comparative summary (see Table 6), followed by a lessons-learned matrix (see Table 7) and detailed case summaries. The goal is not to suggest a one-size-fits-all model, but to distil practical, context-relevant lessons to inform Indonesia's strategy and ensure that its future investments align with local risks, institutional capacity, and long-term development goals.

Table 6: A comparative summary of giant sea walls across the globe

Project (Location)	Length/type	Primary objectives	Key features	Estimated cost	Lessons learned
Tōhoku sea wall (Japan)	400+ kilometres/ Onshore	Tsunami protection	Multi-tiered tsunami management; post-disaster funding; high walls in populated areas	US$12–13 billion	Hard defences alone are not enough Social licence and ecological trade-offs are critical
Afsluitdijk (Netherlands)	32 kilometres/ Estuary dam	Flood protection, land reclamation, freshwater supply	Created IJsselmeer freshwater lake; long-term economic value	US$2.3 billion (2024 value)	Long transition for water quality Dedicated institutions are essential
Delta Works (Netherlands)	30+ kilometres/ Multiple barriers	Storm surge protection	Mix of closeable and fixed barriers; adaptive, ecological adjustments	US$300–500 million per kilometre (for closeable dykes)	Adaptive design and central oversight are vital Start with tailored, ecologically sensitive design
Saemangeum (South Korea)	33.9 kilometres/ Reclamation and sea wall	Land reclamation, industrial/ agricultural development	Created new industrial zones and reservoirs	KRW 22.2 trillion (approximately US$18.5 billion)	Long lead times, poor initial water quality, and ecosystem loss triggered reforms
Sihwa Tidal Power Plant (South Korea)	12.7 kilometres/ Tidal barrage	Renewable energy, flood control, water supply	World's largest tidal power plant; reservoir flushing improved water quality	US$560 million	Tidal flushing restored ecological function Integrated energy-water gains credibility

Table 7: Summary of lessons learned from giant sea wall projects

What worked	What did not work
• **Strong risk justification mobilised public and political support.** • **Projects initiated after devastating floods or clear and present risks, such as the 1953 Dutch flood or the 2011 Tōhoku tsunami, secured faster approvals, funding, and public backing.**	• Opposition emerged where risk perception was low. • Giant sea walls proposed without a widely recognised flood threat faced resistance from communities, non-governmental organisations (NGOs), and academics, especially where coastal ecosystems or fisheries were at stake.
• **Multi-functional design enhanced value.** • **Combining flood protection with land reclamation, economic development, freshwater supply, or renewable energy helped justify high capital costs (e.g., Delta Works, Saemangeum industrial zone, and NCICD's toll-road integration).**	• Narratives focused only on flood risk were insufficient. • Projects struggled to gain support when benefits beyond physical protection were not clearly articulated, especially where costs to the environment or social fabric were high.
• **Cost recovery was linked to a broader development strategy.** • **While the sea walls themselves generated no direct revenue, many projects embedded land reclamation, urban expansion, port development, or energy systems that enabled indirect monetisation.**	• Budget blowouts were common as giant sea walls are expensive. • Most projects exceeded initial estimates, with basic offshore walls costing US$100–150 million per kilometre and closeable barriers costing two to four times more.
• **Flexible design allowed for ecological or social adaptation.** • **Projects that evolved over time (e.g., modifying sluices in Delta Works to restore tidal flows) demonstrated better long-term alignment with environmental and community needs.**	• Closed sea walls led to persistent water quality problems. • Coastal reservoirs created behind dykes (e.g., Sihwa, Saemangeum) often experienced stagnation, algal blooms, and poor water quality for decades, impacting ecosystem recovery and community acceptance.
• **Proactive stakeholder engagement improved legitimacy.** • **Where governments engaged coastal communities early and transparently (e.g., through public consultation, co-design), social licence was enhanced.**	• Lack of early consultation led to public backlash. • Top-down implementation without community input (e.g., in parts of Japan's Tōhoku wall) sparked protests and long-term dissatisfaction, especially when ocean views and beach access were lost.

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Tōhoku, Japan

Following the devastating 2011 Tōhoku earthquake and tsunami, which claimed over 18,000 lives and caused massive economic loss, Japan launched one of the world's largest coastal protection initiatives: a system of over 400 kilometres of sea walls along the northeastern coast of Honshu (see Figure 7).

Construction began in 2012, and as of 2024, it is almost complete, with an estimated cost exceeding US$12 billion. In many places, the new sea walls replaced or upgraded older defences that had failed during the 2011 tsunami.

Figure 7: Tōhoku sea wall in Japan[31,32],

Source: Haskoning and WitteVeen+Bos.

Project rationale
The primary objective was to reduce fatalities and infrastructure damage in future tsunami events, especially in high-risk, densely populated areas. The sea walls comprise concrete barriers, often 10 to 15 metres high, designed to protect coastal towns from tsunamis – particularly those with a one-in-100-year return period known as Level 1 tsunamis – and are part of a broader multi-layered tsunami risk management strategy that includes early warning systems, vertical evacuation structures, land-use zoning, and relocation of settlements to higher ground.

Project organisation
The initiative was led by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MOLIT), in close coordination with prefectural governments. Funding came largely from the national government's post-disaster reconstruction budget, with local governments responsible for implementation and maintenance in collaboration with engineering contractors.

Project financing
Financed through Japan's Reconstruction Agency and national disaster response budget, the project did not follow a PPP model; instead, it was treated as a public good and an urgent reconstruction priority. The total cost was roughly ¥1.35 trillion (approximately US$12–13 billion).

Project execution challenges
While the Tōhoku sea wall was developed as a monumental response to the 2011 tsunami disaster, its implementation faced social and cultural challenges. Coastal communities criticised the wall for severing their long-standing connection to the ocean, which was an integral part of their identity, economy, and way of life. In fishing villages that once relied on direct access to the sea, residents ended up facing a structure that limited their coastal access and altered the traditional landscape. This disconnect raised concerns about the long-term social sustainability of hard infrastructure solutions and the need to balance physical protection with community cohesion and cultural preservation.[33,34]

Project impact and value generation

- **Risk reduction:** The new sea walls are designed to protect over 100 coastal towns from smaller Level 1 tsunamis and reduce damage even under extreme events, such as Level 2 tsunamis.
- **Controversy:** In many areas, the towering walls blocked ocean views, restricted beach access, and disrupted community connections to the sea. Some residents protested, arguing for smaller or differently designed structures.[35]
- **Ecological impact:** Environmental groups raised concerns over damage to coastal habitats, estuaries, and the natural landscape. In some areas, coastal ecosystems have been altered or destroyed.
- **Economic resilience:** The sea walls aim to protect critical infrastructure, fisheries, and tourism assets. However, concerns remain about whether they are sufficient for long-term community sustainability in ageing, shrinking coastal towns.

Lessons learned

- **Over-reliance on hard infrastructure is risky:** Even the best-engineered sea walls cannot fully protect against extreme events. In some cases, walls give a false sense of security and discourage evacuation.[36]
- **Multi-layered strategies work best:** Japan's approach evolved to include land-use planning, education, and vertical evacuation alongside structural defences. This holistic approach enhances resilience.
- **Community engagement matters:** Strong resistance in some towns revealed the importance of early consultation, transparent communication, and co-designing with local communities.[37]
- **Long-term maintenance and adaptation:** Coastal defences require regular upgrades and must be capable of adapting to rising sea levels and changing risk profiles over time.

Relevance to Indonesia's Giant Sea Wall project

Japan's experience underscores that scale alone does not ensure success. Key takeaways relevant to Indonesia's Giant Sea Wall project include the importance of:

- Prioritising risk-informed design thresholds based on local hazard modelling;
- Embedding sea walls within a broader adaptive, multi-layered protection framework;
- Anticipating and addressing social and environmental trade-offs; and
- Establishing a long-term governance model that enables maintenance, monitoring, and public trust.

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Afsluitdijk, the Netherlands

The Afsluitdijk is a 32-kilometre long dam in 6.5 metre-deep water that connects the provinces of North Holland and Friesland (see Figure 8). It cost €125 million to build in 1932, which translates to US$2.3 billion or US$72 million per kilometre in 2024 terms. By shortening the coastline from its original 300 kilometres to 32 kilometres, the dam has helped to reduce maintenance costs and facilitate flood protection.

Figure 8: Afsluitdijk in the Netherlands[38]

Source: Traveler's Universe.

Project rationale

The sea wall had three original objectives, which were to: protect the central Netherlands from flooding; increase food supply by developing agricultural land reclamations; and improve water management by creating a freshwater lake.

Project organisation

While the Afsluitdijk was constructed under the direction of the Ministry of Public Works (*Rijkswaterstaat*), who is its project owner and authority, a new dedicated organisation (*Dienst der Zuiderzeewerken*) was also established for the development of the land reclamations and management of the reservoir. This organisation existed between 1935 and 1971.

The Afsluitdijk is a solid sea wall that has required little maintenance over the past 75 years. However, in the last decade it has become clear that major renovation is required, mainly due to sea level rise and climate change. Earlier in May 2018, *Rijkswaterstaat* awarded the contract for the renovation of the Afsluitdijk to the Levvel consortium – comprising Invesis, Van Oord Aberdeen Infrastructure Partners, and Rebel – under a 30-year PPP agreement. During this period, Levvel will be responsible for the design, construction, financing, and 25-year maintenance of the Afsluitdijk.[39]

Project financing

The renovation project was procured as a design-build-finance-maintain (DBFM) PPP, with an estimated total project cost at approximately €550 to 921 million, of which €330 million is provided by the European Investment Bank (EIB) under the Juncker Plan's European Fund for Strategic Investments (EFSI) guarantee.

While the sea wall itself does not generate revenue, it enables broader economic activity that could justify adjacent investments or local development, such as tourism (walking or cycling infrastructure, Wadden Sea United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage site); renewable energy (pilot tidal and solar energy infrastructure such as the Blue Energy project at Breezanddijk); as well as real estate and logistics (increased land value behind the dam due to improved flood safety). The reservoir behind the dam is also used to secure water supply in times of drought.

Project execution challenges
A number of steps were implemented to mitigate potential adverse social and environmental effects during the Afsluitdijk's renovation. Construction activities were planned outside of migratory and breeding seasons to conserve wildlife, especially sensitive and protected species, and artificial lighting was restricted to minimise bat disturbance. With provisions for the identification and preservation of priceless objects, archaeological remnants found along the dam, particularly those close to navigation and sluice complexes, were protected under the Monuments Act.

The highway's traffic was also impacted, with accidents or delays during peak hours resulting from lanes merging between Den Oever and Kornwerderzand. Additionally, the construction of new tide locks at Den Oever and Kornwerderzand also caused disturbances to ship traffic; however, these disruptions were kept to a minimum by minimising the length of time that the vessels were blocked.

Project impact and value generation
By transforming the Zuiderzee into the freshwater Ijsselmeer earlier in 1930, the Afsluitdijk has created a vital source of water for drinking and agriculture.[40] However, despite significant water sanitation efforts, the water quality remains moderate, with some algal bloom due in part to the leaching of fertilisers from agricultural activity.

At a width of 25 metres and a length of 140 metres, the proposed new lock at Kornwederzand under the ongoing renovation project will be equipped to handle deeper and bigger vessels, generating a boost to shipyards, coastal shipping firms, and fisheries. Additionally, by ensuring that fish are able to migrate from saline to fresh water and back again to complete their lifecycles, the fish migration river will contribute to the improvement of biodiversity.

Lessons learned
While the project was originally welcomed as a major flood protection intervention and opportunity for reclamations, fishermen and fishing communities protested the impacts on their livelihoods. It took decades before the socio-economic and ecological transformation of the inland sea to a well-functioning freshwater reservoir was completed and communities were able to adjust to the new situation. This project

underscored the importance of integrating ecological and social considerations into large-scale engineering works. Additionally, the *Dienst der Zuiderzeewerken*, the dedicated implementing organisation, had beens critical to driving execution and securing the success of the project.

Relevance to Indonesia's Giant Sea Wall project
The Afsluitdijk offers a long-term perspective on integrated flood protection, water resource management, and adaptive governance. Key takeaways relevant to Indonesia's Giant Sea Wall project include the importance of:

- Designing with multifunctionality in mind, as the Afsluitdijk served not only enabled flood control but also land reclamation, freshwater creation, and later, tourism and renewable energy infrastructure; and
- Anticipating long-term ecological and social transitions, as it took decades for the transformation from saltwater to freshwater systems to stabilise, and to overcome the initial opposition from fisheries with social adaptation strategies.

Deltawerken, the Netherlands
The Deltawerken sea wall consists of several dams closing off estuaries (see Figure 9). The most expensive barrages comprised large, closeable gates and costing US$300 to 500 million per kilometre, while more basic dams were built at US$75 to 200 million per kilometre, depending on water depths.

Its key dams include:

- **Maeslantkering**, moveable storm surge barrier that is one kilometre long and up to 15 metres deep. Opened in 1997, it protects the port of Rotterdam and its surrounding areas from extreme storm surges;
- **Haringvlietkering**, a 4.5 kilometre-long and 10-metre-deep dam with sluice gates to regulate water levels in the Rhine-Meuse delta, allowing excess river water to be released into the sea and preventing saltwater intrusion;
- **Grevelingendam**, a 6-kilometre-long and up to 25-metre-deep dam that separates Grevelingen Lake from the North Sea, initially built to close off the estuary and reduce flood risk; and
- **Oosterscheldekering**, a 9-kilometre long and up to 25-metre-deep moveable storm surge barrier that protects the province of Zeeland while preserving the tidal ecosystem.

A few saltwater reservoirs remain behind the dykes for aquaculture ecosystems, in addition to a few freshwater ones for water supply and irrigation purposes.

Figure 9: Deltawerken in the Netherlands[41]

Source: Eindhoven University of Technology.

Project rationale
Following a major flood in 1953 which caused the death of 1,800 people and significant economic damage when agricultural land was submerged in seawater, 700 kilometres of existing dykes were replaced with 30 kilometres of new dykes and flood gates between 1960 and 2000.

Project organisation
The project's strategy and conceptual designs were overseen by the Delta Committee, an organisation comprising high-level governmental officials, senior engineers, and academics. Today, the Delta Committee remains active in formulating long-term flood protection strategies for the Netherlands. A dedicated organisation known as the *Deltadienst* (Delta Agency) operating under the Ministry of Public Works was also established for project execution.

Project financing
Early construction from the 1950s to 1997 was publicly funded by *Rijkswaterstaat* without toll or user revenue models, as the project was designed purely for flood protection and water management. However, for its modern upgrade requirements, the Deltawerken has leveraged PPP with DBFM approaches. While it does not directly generate revenue, it provides economic returns and enables indirect monetisation through coastal development and urban expansion of the region adjacent to the wall, value retention for the agricultural sector, and port development of Rotterdam and Zeeland.

Project execution challenges
The execution of the Delta Works project was marked by substantial challenges stemming from its unprecedented scale and complexity. As a multi-decade undertaking, the project demanded sustained political commitment, long-term financing, and continuous adaptation of engineering methods to evolving environmental conditions andtechnical standards.

Coordinating the design and construction of multiple dams, sluices, storm surge barriers, and dykes across different estuaries required meticulous planning and inter-agency collaboration. Moreover, the need to integrate flood protection with ecological preservation introduced additional complications, especially as public awareness of environmental impacts grew over time.

Project impact and value generation
The shortening of the coastline had resulted in major impacts on ecosystems, including the loss of spawning grounds. Freshwater quality remains moderate with some algal blooms, and the water is used mainly for irrigation purposes. In addition to enhancing flood safety, the dykes have created gentle water conditions behind its structures that have benefitted aquaculture, tourism, and recreation. Currently, the area also hosts wind farms and tidal energy pilots, with private companies undertaking partnerships with the government to develop renewable energy on or near Deltawerken.

Lessons learned
This project has highlighted the need for adaptive and environmentally-sensitive engineering solutions. Designs were adjusted and dams were retrofitted during implementation – a process that remains ongoing – to mitigate impacts on ecology and fisheries. The general and political opinion is that a more tailored approach should have been applied from the start of the project, taking into account impacts on ecology and fisheries. Another important lesson for Indonesia as it advances on its Giant Sea Wall initiative is the value of having a dedicated institutional body, such as the Netherlands' *Rijkswaterstaat*, to coordinate planning, design, construction, and long-term maintenance. Centralised oversight enables better integration across environmental, technical, and social dimensions.

Relevance to Indonesia's Giant Sea Wall project
The Deltawerken illustrates the importance of phased, adaptive, and ecosystem-aware design in long-term flood resilience. Key takeaways relevant to Indonesia's Giant Sea Wall project include the importance of:

- Recognising that non-revenue-generating flood infrastructure can still enable indirect monetisation through urban expansion, aquaculture, agriculture, port development, and renewable energy pilots near infrastructure; and
- Designing for multi-functional use, as the project has evolved to support tidal energy, wind power, recreation, and aquaculture, illustrating how sea wall infrastructure can enable long-term socio-economic benefits beyond protection alone.

Saemangeum, South Korea

Located on the southwest coast of South Korea near Gunsan City, the Saemangeum sea wall possesses tidal flood gates to drain river water and flush the reservoir (see Figure 10). Construction took place between 1991 and 2010, over a total area spanning 291 square kilometres of reclaimed land and 118 square kilometres of artificial lake.

Figure 10: Saemangeum Sea Wall in South Korea[42]

Source: Indozone Fadami.

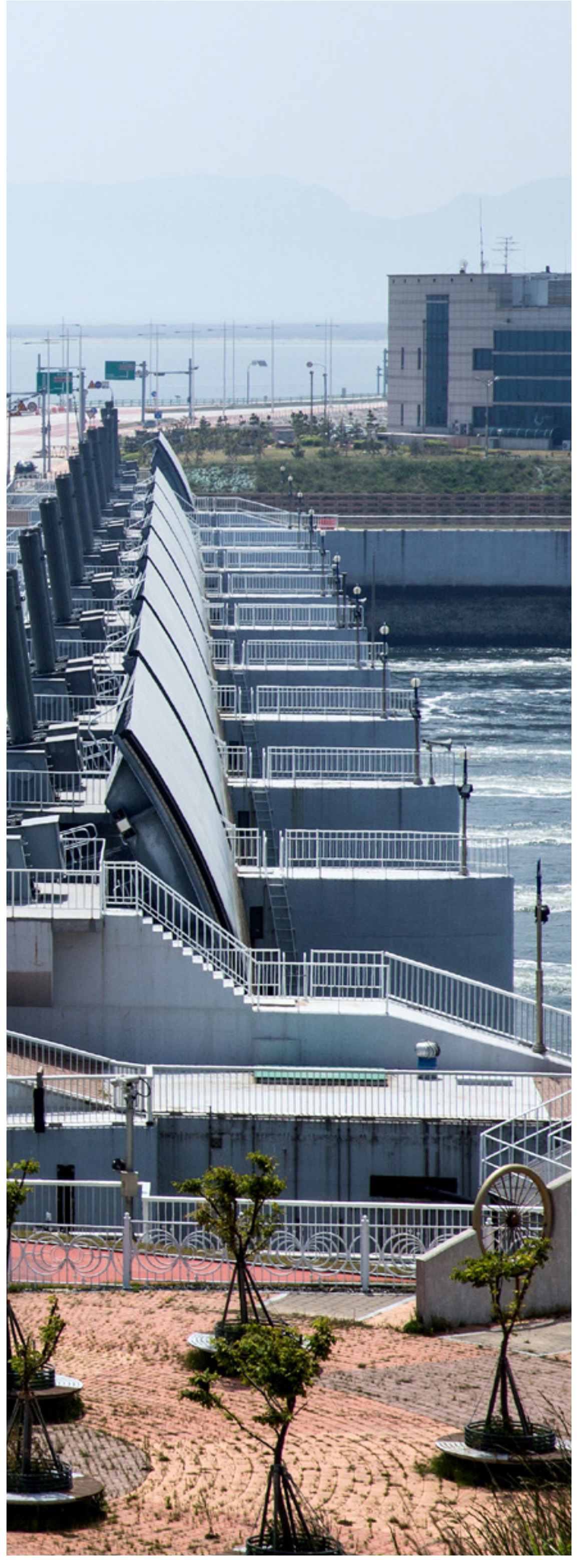
Project rationale
The Saemangeum Sea Wall was mainly designed to reclaim land for agricultural, urban, and industrial purposes. Flood protection was also a goal, albeit not the primary objective.

Project organisation
The project is managed by the Saemangeum Development and Investment Agency (SDIA), which falls under the Ministry of Land, Infrastructure and Transport (MOLIT), and oversees all its planning, investment, and implementation aspects.

Project financing
The sea wall was financed through a blended public-private investment model. Central government and provincial authorities contributed approximately ₩10.9 trillion and ₩0.9 trillion respectively, while private investors provided around ₩10.3 trillion, for a total of approximately ₩22.2 trillion in funding.

Furthermore, once the sea wall is completely built, SDIA spearheaded the development of reclaimed land inside the dyke. The development, which accounts for 219 km^2 is planned to be developed in four phases between 2020 to 2050. The reclaimed land will serve as the economic hub of Northeast Asia by promoting industry, business, and tourism.[43]

Project execution challenges
The project encountered multiple challenges from its earliest stages – politically, the project purpose is questioned as it intersects between development-driven and environmental accountability.[44] Socially, The reclamation disproportionately impacted low-income fishing communities, disrupting livelihoods and traditional coastal practices. This unequal impact became a flashpoint for environmental justice critiques, as these communities were excluded from project benefits while bearing most environmental costs.[45] The Saemangeum Sea Wall led to the loss of 401 km² of tidal flats, causing a 95–97% decline in migratory shorebirds and severe habitat loss, while altered tidal flows triggered persistent red tides, hypoxia, and long-term ecological degradation. These impacts make it a cautionary example of how large-scale reclamation can cause irreversible environmental harm.[46,47]



Project impact and value generation
The sea wall took 19 years to build, and SDIA is planning to build a reclamation inside the wall for a township which includes an industrial complex, research institutions, business areas, housing, and schools. Ongoing socio-economic development is underway in the Saemangeum National Industrial Complex and Saemangeum Tourism and Leisure Site, as well as floating solar, wind, high-tech agriculture, and bio-industry sectors. Nevertheless, water quality remains a challenge due to fertiliser leakages from agriculture.

Fisherina Co., Ltd, together with SDIA and the Ministry of Oceans and Fisheries, also undertook a private investment project to build Bieung Port at the endpoint of Saemangeum Sea Wall No.4 – a first for South Korea. Linked to the Saemangeum project, Bieung Port is a multi-functional tourist complex that serves as a part of the inner port of Gunsan and a fishing base. It houses a large seafood market and sashimi restaurants, and serves as a base for tourist cruise tours around the Gogunsan Islands.

Lessons learned
The Saemangeum Sea Wall project underscores the ecological risks of large-scale land reclamation, and has prompted increased awareness and policy measures for wetland conservation and sustainable development practices in South Korea.

Relevance to Indonesia's Giant Sea Wall project
South Korea's Saemangeum project demonstrates the scale and complexity of integrating coastal defences with land reclamation and long-term economic development. Key takeaways relevant to Indonesia's Giant Sea Wall project include the importance of:

- Clarifying primary project objectives and managing project prioritisation, project design, and stakeholder expectations from the outset, especially in the case of the Saemangeum project whose primary objective was land reclamation for agriculture, industry, and urban development, with flood protection as a secondary objective; and
- Recognising that large-scale reclamation can generate long-term economic value, but only when supported by clear planning, investor engagement, and appropriate institutional coordination, as seen with the SDIA under MOLIT.

Sihwa Lake, South Korea

The Sihwa Lake Tidal Power Station is the world's largest tidal power installation situated at a 43.8-square kilometre artificial reservoir created by a 12.7-kilometre sea wall built from 1994 to 2011 to reclaim land, control flooding, and secure irrigation and freshwater for nearby industrial areas (see Figure 11).

Figure 11: Sihwa Lake Tidal Power Station[48]

Source: Sihwa Lake Tidal Power Station. "The World's Largest Tidal Power Station". 2022.

Project rationale
The sea wall initially aimed to create freshwater lakes for agriculture and industrial use, flood control, and land reclamation. It was constructed to secure agricultural water by turning the coastal reservoir into freshwater, mitigate flooding, and provide reclaimed land for the surrounding metropolitan region.

Project organisation
State-owned Korea Water Resources Corporation (K-water) is the owner of this project. Environmental impact assessments, turbine design, and infrastructure construction were carried out by engineering and equipment contractors such as Daewoo engineering and construction, Andritz Hydro, with ministries coordinating the initiative.[49]

Project financing
The project, which included the 254-megawatt tidal power plant (completed in 2011) and the 12.7-kilometre sea wall (completed in 1994), cost about US$560 million.[50] No private sector involvement or PPP frameworks were involved; all funding came from the government through K-water.

Project execution challenges
The execution of the Sihwa Tidal Power Plant faced major environmental and technical challenges, particularly after the initial closure of the sea wall in the 1990s. Natural tidal currents were blocked, and with limited freshwater inflow and increasing wastewater from nearby industrial complexes, water quality within Sihwa Lake rapidly deteriorated.

By 1997, contamination was so severe that the lake's water was no longer usable. Construction delays in wastewater treatment facilities worsened the issue. To address this, the government shifted the lake's management approach from freshwater retention to periodic seawater flushing through sluice gates, though this had limited impact. Consequently, K-water initiated a feasibility study for a tidal power plant to enhance seawater circulation by an estimated 200%.[51]

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Project impact and value generation
About half of Sihwa Lake's total water volume is made up of the 160 million tonnes of water that enter and exit its floodgate and waterwheel. Water quality has improved because of the constant flow of water between the lake and the outer sea throughout the power generation process.

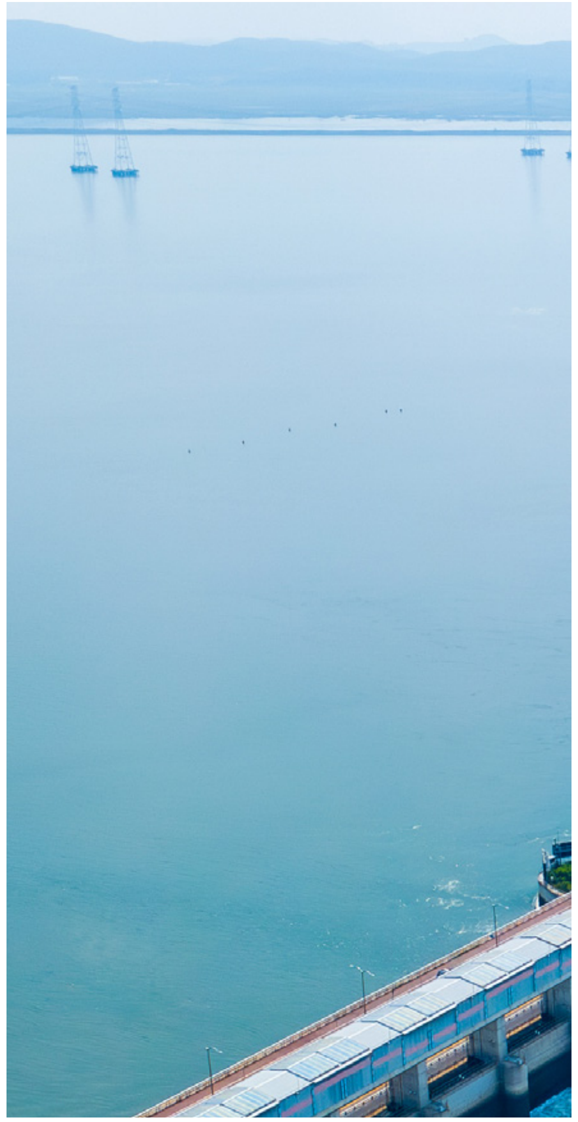
Annual tidal flushing of approximately 60 billion cubic metres of seawater also helped to reduce chemical oxygen demand (COD) from 17 to around 2 parts per million, restoring ecological balance and wildlife recovery, including habitats for over 146 bird species.

Through the provision of green energy, the Sihwa Lake Tidal Power Plant has contributed to South Korea's energy self-sufficiency goals. It has the capacity to reduce carbon emissions by 315,000 tonnes annually, reduce petroleum imports by 862,000 barrels annually, and provide electricity for a population of 500,000.[52]

Lessons learned
For Indonesia's Giant Sea Wall, the Shihwa Coastal Reservoir offers a cautionary lesson on the risks of enclosing coastal waters without first ensuring upstream pollution control. Despite over US$1.5 billion in rehabilitation—more than double the original construction cost—water and sediment quality in Shihwa remain degraded due to persistent inflows of pollutants, highlighting the need for integrated watershed management before, during, and after enclosure. This case underscores that large-scale coastal infrastructure, if poorly sequenced, can damage ecosystems, strain budgets, and still fail to achieve its intended outcomes.[53]

Relevance to Indonesia's Giant Sea Wall project
South Korea's Sihwa Tidal Power Plant illustrates the complexities of integrating coastal defence with water management and energy production. Key takeaways relevant to Indonesia's Giant Sea Wall project include the importance of:

- Designing for multifunctionality, by integrating flood protection with additional uses such as water storage, land development, or even renewable energy, to improve project feasibility and public acceptance;
- Evaluating long-term environmental implications, as seen in Sihwa's initial ecological degradation, which necessitated retroactive modifications like tidal turbine installation to restore water circulation; and



- Incorporating ecological and water quality assessments into early design phases to avoid costly and difficult retrofits.

These global case studies highlight the immense potential and complexity of giant sea wall initiatives. They show that success depends not only on engineering excellence and financial resources, but also on choosing the right strategy for the right context.

As Indonesia charts its path forward, the next chapter will examine the full spectrum of coastal protection strategies, along with the types of solutions that can be deployed. Understanding this broader menu of options is essential to ensure that any future investment in the Giant Sea Wall aligns with local conditions, community priorities, and long-term resilience goals.

Chapter 5
A tailored approach for the North Java coastline

Ultimately, any strategic intervention along the North Java coastline must be designed and implemented with a clear understanding of the region's complex and localised challenges – including but not limited to severe land subsidence, sea level rise, monsoon patterns, and diverse geology. These conditions create varied vulnerability profiles across the different areas supporting dense populations, major infrastructure, aquaculture, and industrial zones.

For example, while building the sea wall in Jakarta, Banten, and Bekasi is an important step, experts have noted that without ongoing upgrades, protection may not be long-lasting. Some also argue for a segmented approach tailored to subsidence levels and soil conditions, and avoiding unnecessary construction in stable areas. In this regard, Japan's Tōhoku Sea Wall, which extends over 400 kilometres but was not designed as a uniform barrier, provides a relevant example of how protection strategies can be tailored to local geomorphological, ecological, and socio-economic conditions, as well as wave exposure and elevation levels, through the use of both hard and hybrid solutions.

As a first step, Indonesia's priority should be to leverage existing information to launch targeted, high-impact coastal initiatives that could serve as scalable models and build the momentum for broader, long-term solutions. A multi-criteria, spatially disaggregated approach grounded in comprehensive risk mapping is essential to ensuring that infrastructure investments respond to localised hazards and are cost-effective.

To this end, we propose augmenting existing mapping systems with integrated coastal system modelling that combines land subsidence, sea level rise, hydrodynamics, and socioeconomic impacts, as was done for Deltawerken in the Netherlands. This could also entail developing a North Java Coastal Risk Information System (CRIS) to centralise study findings, hazard layers, and strategy options, a practice used in South Korea and the UK to support stakeholder-informed decision-making.

Mapping risk areas

Mapping activities carried out by the Coordinating Ministry for Economic Affairs (CMEA) have revealed varying degrees of coastal vulnerability along the North Java coastline, shaped primarily by the following three drivers:

01. Coastal abrasion, a key indicator of coastline instability, with shorelines retreating at an average of approximately 279.1 metres per year across the region, wherein Demak Regency in Central Java exhibits the highest rate of abrasion and Bekasi Regency in West Java demonstrates the highest rate of accretion;[54]

02. Coastal inundation, with areas such as West Bekasi, Pekalongan, Tuban, and Lamongan Regencies facing moderate to high flood risk due to elevation and exposure to storm surges and high tides, while East Bekasi and Central Jepara Regencies are classified as relatively low-risk zones;[55]

03. Land subsidence from excessive groundwater use, resulting in the region becoming highly exposed to erosion and flooding despite low wave energy along the North Java coastline, which highlights the need for localised intervention strategies as well as policies and regulations around groundwater extraction.[56]

Example of flood risk mapping along the north coast of Java

By mapping each of the three following factors, we can identify the areas that are most vulnerable and prone to flooding. Note, however, that the proposed thresholds below are given by means of an example, and should not be considered indicative:

01. Coastal zones located below a mean sea level (MSL) of 5 metres: A digital elevation model (DEM) should be used to identify these zones for further analysis below.

02. Need for protection, based on population density, existing critical infrastructure, and strategic land use:

A. Population density:
   i. High density: More than 1,500 inhabitants per square kilometre
   ii. Medium density: 500 to 1,500 inhabitants per square kilometre
   iii. Low density: Less than 500 inhabitants per square kilometre

B. Presence of critical infrastructure, such as airports, seaports, train stations, toll roads, and industrial zones

C. Strategic land use (e.g., *Lahan Sawah Dilindungi* (LSD))

03. Land subsidence rate:

A. High rate: More than 10 centimetres per year

B. Medium rate: 1 to 10 centimetres per year

C. Low rate: Less than 1 centimetre per year

Selecting a strategy

Once the risk areas have been mapped, the next step is to select context-specific coastal protection strategies using data on sea levels, population density, economic value, and land subsidence to guide decision-making and justify investment. To carry this out, we can also introduce a multi-criteria analysis (MCA) tool to select strategies based on land value, population density, hazard level, and engineering feasibility, as implemented in coastal planning in Japan and Bangladesh.

It is important to recognise, however, that while factors such as elevation, infrastructure, population density, and land subsidence are critical, they should not be the sole determinants for sea wall design. Coastal system variability and the characteristics of the surrounding natural environments will also significantly influence the type of intervention required. For instance, sea wall designs in estuarine areas will differ from those on open coastlines, just as approaches for wave-dominated coasts will differ from tide-dominated ones.

In certain locations, the presence of natural features, such as coastal forests, may allow for integration with nature-based solutions. Therefore, a mapping of coastal typologies (e.g., open coast vs. estuary, wave- vs. tide-dominated environments, and existing natural assets) will also be valuable for the assessment and selection of the appropriate coastal protection zones.

Go Forward strategies

Go Forward strategies are typically pursued in areas that are densely populated or have high economic value, where the high cost of forward defence measures can be justified. These locations often experience high rates of land subsidence and/or face increasing challenges in maintaining the current coastline. In such cases, there is a justification for the shift towards offshore defences and land reclamation.

Long-term spatial planning may also offer more viable solutions here. If a Go Forward approach is selected, one must assess its technical feasibility, based on factors such as bathymetry, soil composition, and inputs from engineering assessments. Similar strategies have been adopted in South Korea and greater Tokyo, where offshore defences have enabled urban expansion and infrastructure development.

Defend strategies

Defend strategies are generally suitable for areas that have moderate to high population density and economic value, but where the coastline remains relatively stable or shows accretional trends, with manageable subsidence rates. In such zones, it is technically and economically feasible to maintain the existing coastline through a mix of green and grey interventions, such as sea walls, revetments, mangrove rehabilitation, and breakwaters. Comparable strategies have been practiced in Vietnam and the Netherlands, where layered defence approaches utilised, combining hard infrastructure with mangrove restoration and buffer zones.

Restructure strategies

For areas with low population densities and limited economic assets, the costs of intensive coastal defence measures are generally not justifiable. In these instances, the decision process shifts towards the evaluation of local coastal conditions – specifically, rates of erosion and land subsidence, which can be assessed with field data and remote sensing tools.

Restructure strategies are most appropriate in areas that have experienced severe coastal retreat, persistent erosion, and significant subsidence over time, or areas where the coastline has retreated in the past 30 years due to abrasion or subsidence. In these locations, defence of the current coastline is usually not viable, especially when there are increasing rates of sea level rise and continued subsidence.

In such cases, managed retreat, land use transformation, and the restoration of natural buffers like mangroves and wetlands become the most viable and sustainable approaches. Experience from the US (e.g., New York state's buyout programs)[57] and Fiji highlight the need for legal, land tenure, and social support frameworks to implement retreat strategies humanely and effectively.

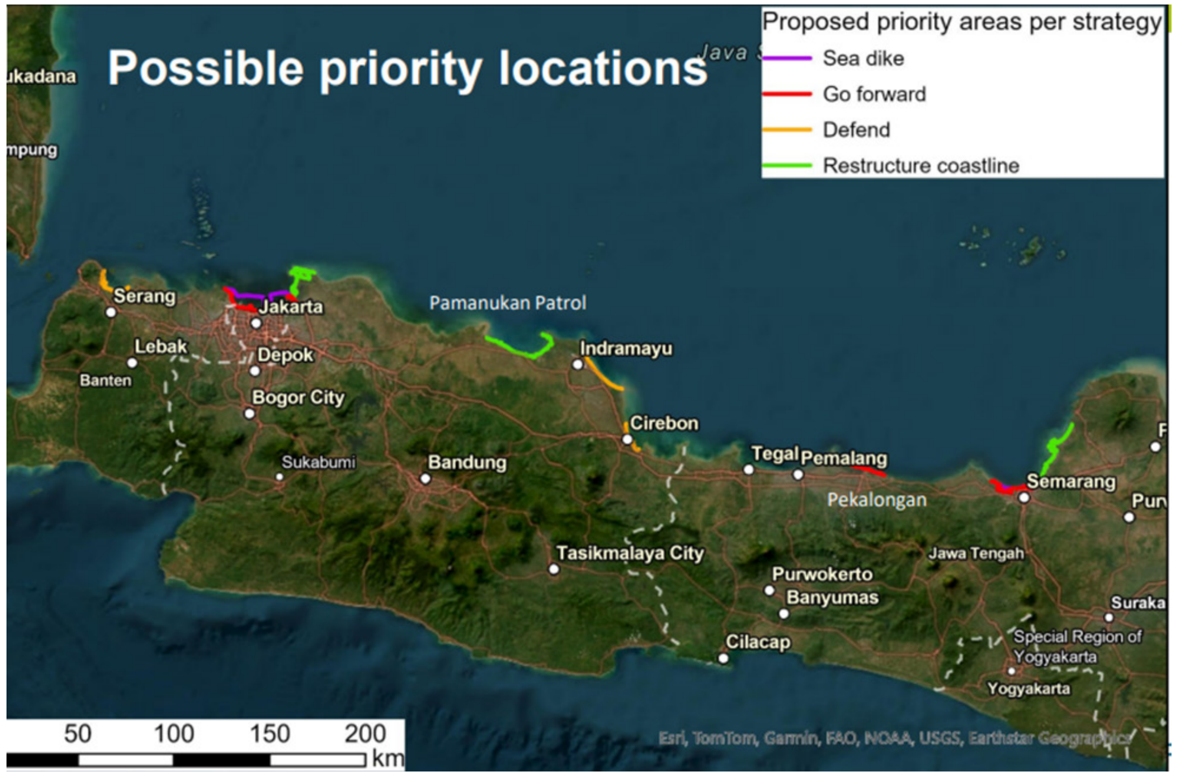
Prioritising locations

To test the effectiveness of the chosen approach, it is necessary to prioritise locations for pilot projects before the lessons learned are applied to a broader implementation. In this regard, the prioritisation approach we have adopted aligns closely with recommendations by the Japan International Cooperation Agency (JICA), where population density, subsidence rate, and economic value are used as key criteria.

Accordingly, we have selected the following priority locations for each coastal protection strategy (see Figure 12):

- **Jakarta, Semarang, and Pekalongan:** Given that these three densely populated cities serve as major economic hubs – Jakarta as the nation's capital, Semarang as an industrial centre, and Pekalongan as a hub for the batik industry – and are experiencing severe land subsidence of between 6 to 11 centimetres per year, we recommend the use of Go Forward strategies.
- **Serang, Cirebon, and Indramayu:** Given that conventional coastal defence measures are feasible and appropriate in these areas, we recommend the use of Defend strategies.
- **Demak, Pamanukan Patrol, and northwest Jakarta:** Given that strategic retreat and land use transformation are likely to offer more sustainable long-term outcomes, we recommend the use of Restructure strategies.

Figure 12: Mapping possible priority locations[58]



Source: Haskoning.

To ensure transparency, a formal prioritisation framework should be adopted based on risk, value, and technical feasibility. It may also be worthwhile to consider including future climate scenarios to test the long-term viability of the selected locations, particularly the ones with high subsidence and limited groundwater management.

Developing a tailored approach for the Giant Sea Wall project

The implementation of coastal protection strategies without adequate and comprehensive planning could lead to unintended consequences and community resistance. Fragmented approaches also run the risk of missing out on opportunities for integrated coastal development that could address multiple challenges simultaneously.

As demonstrated by the Netherlands, the adoption of adaptive pathway planning approaches that embed trigger points for action (e.g., subsidence rates or sea level thresholds) enables strategies to be adjusted over time, thereby facilitating more flexible decision-making and greater responsiveness to uncertainties in climate, population growth, and economic development.

Coastal projects should also be evaluated through a co-benefit lens, with the quantification of potential benefits for biodiversity, public health, recreation, carbon sequestration, and community well-being. Such approaches have been successfully institutionalised in Singapore's Active, Beautiful, Clean Waters (ABC Waters) Program and the US Environmental Protection Agency (EPA)'s Green Infrastructure Program.

To date, coastal protection initiatives along the North Java coastline have been developed in isolation, each addressing specific local challenges. Scaling successful coastal protection will require both a plan for the entire North Java coastline, as well as a master plan for each unique region to identify optimal approaches to maximise benefits while minimising negative impacts on communities and ecosystems.

We propose the following three phases to develop a tailored approach for the Giant Sea Wall projects:

Phase 1: Alignment and refinement of regional coastal plan

Every coastal protection project should begin by ensuring clear alignment with regional planning priorities, including considerations for technical feasibility, land use mapping, future scenarios, and economic viability.

Leveraging a decision framework similar to the one we have profiled in this chapter, the government can then prioritise locations based on coastal system variability and natural environmental characteristics, tailoring interventions – such as Go Forward, Defend, or Restructure strategies – to regional conditions, such as coastal typology and natural buffers (e.g., mangroves, coastal forests).

To support this process, a regional knowledge platform, similar to South Korea's coastal management portals, could be developed to consolidate data on hazards, infrastructure, ecosystems, and communities. Ultimately, the objective is to develop a regional coastal protection master plan to provide clear technical guidelines, assign responsibilities across government levels, and build on existing local knowledge and experience to accelerate coordinated, context-specific action.

Phase 2: Project area agreement

Once regional alignment has been achieved, the next step is to define specific project areas through structured agreement processes. This includes ensuring coherence with line ministries, harmonising with local legislation and regulatory frameworks, and identifying quick-win opportunities that can showcase early success and generate momentum for broader implementation.

Project area agreements should incorporate mechanisms for meaningful community engagement, such as representative coastal councils or multi-stakeholder working groups. This participatory model, exemplified by the Deltawerken project, ensures that local voices are integrated into planning and implementation.

Phase 3: Feasibility and design

Finally, comprehensive feasibility studies and detailed project design should be undertaken to address key technical, financial, environmental, and social dimensions, along with scalability for regional replication. Key considerations should include:

- **Social aspects:** Regional planning must account for land ownership and outline resettlement and tenure programs, as shifting land ownership patterns will require multi-year planning. Livelihood transitions also require long-term plans with capacity building and alternative income support. Global examples, such as New York's buyout programs and Fiji's relocation framework highlight the importance of legal mandates and robust social support.
- **Environmental aspects:** Projects should incorporate lessons from past mangrove restoration efforts and seek opportunities to enhance biodiversity and fish stock recovery through sustainable aquaculture tied to community livelihoods.
- **Financial/economic aspects:** Sustainable financing models must support long-term resilience, not just short-term fixes. Projects should examine how socio-economic stability can be maintained over time and identify financing mechanisms for future protection.
- **Technical aspects:** Studies must evaluate how long and to what extent 'danger zone' communities can be protected given climate projections. Designs should preserve natural river flows without increasing upstream or downstream flood risks. Spatial planning agencies must be involved to align protection with broader regional development goals.

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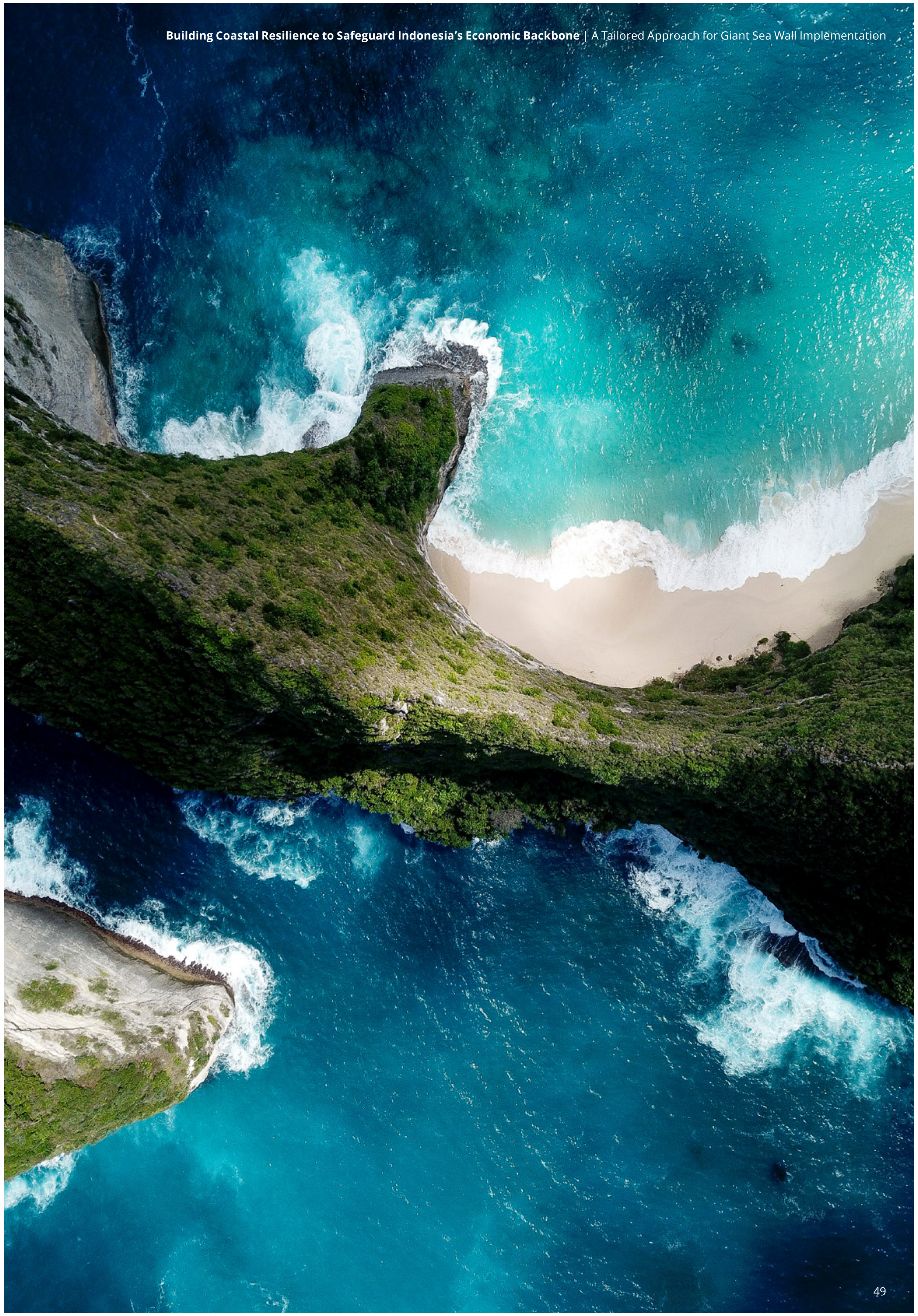

Chapter 6
The way forward: High-level recommendations for the implementation of the Giant Sea Wall

Coastal protection, economic security, and food safety are urgent priorities for North Java. To address these challenges at scale, Indonesia must move from planning to action, starting with pilots in key regions to build the institutional and technical capacity for a broader transformation. Drawing on global lessons and domestic experience, we recommend a programmatic and adaptive implementation strategy, underpinned by fit-for-purpose governance, innovative financing, and a commitment to long-term resilience.

Summary: Five priorities for the Giant Sea Wall project

- **Act now and plan long:** Launch high-impact pilots while building a long-term, adaptive roadmap.
- **Tailor solutions to local context:** Deploy Go Forward, Defend, or Restructure strategies according to local coastal conditions.
- **Build with legitimacy:** Empower a dedicated agency to support the Coordinating Ministry's in coordinating and executing at the regional and national level.
- **Finance innovatively:** Blend public and private capital, focus on value capture, and tap into climate finance.
- **Plan holistically:** Integrate spatial, social, and environmental goals into a unified masterplan with legal basis.

Act now and plan long

The importance of coastal protection and sustainable development is widely recognised. However, given the scale of the Giant Sea Wall's 500 to 946 kilometre-long coastlines, planning and design will require time. While the current administration is prioritising the issue and pledging swift action, it also needs to emphasise the right approach to facilitate execution and prevent delays.

To this end, a dual approach is recommended – specifically, to swiftly execute high-priority pilot projects, while simultaneously developing long-term plans and establishing regulations for each region along the coastline. This method, known as a programmatic approach, sets overarching goals and strategies while allowing gradual implementation to take place through individual projects aligned with the broader framework.

In this regard, the ability to segment, pilot, and sequence implementation will be essential, and we believe the adoption of AI-enabled planning can be of value in:

- Developing schedules more quickly and with higher reliability;
- Coordinating across multiple agencies and delivery zones;
- Identifying and resolving roadblocks before they escalate; and
- Reducing time and cost overruns through better-informed trade-offs.

Accelerating delivery through AI-driven project management

One key challenge for megaprojects lies in developing implementation schedules that are technically robust, comprehensive, and swift enough to match policy ambition. Conventional methods struggle to maintain both quality and scale. Producing a logic-linked schedule that accounts for thousands of interdependent tasks – spanning permitting, environmental safeguards, engineering design, procurement, and stakeholder coordination – can take many months. Even when such schedules are produced, implementation tracking often lags due to data siloes and fragmented reporting.

AI-based tools, such as those developed by Foresight, introduce a step-change to how governments can approach delivery planning. These platforms transform historical project data into strategic analysis, enabling delivery agencies to generate high-quality, logic-linked schedules in a matter of weeks rather than months. Importantly, they do not replace human expertise, but empower planning teams by automating routine tasks, surfacing blind spots, and aligning stakeholders around a shared, evidence-based roadmap. The result is faster mobilisation, greater visibility, and stronger alignment – critical enablers of successful delivery.

By combining AI with the industry's largest databases of schedule and as-built performance, it becomes possible to orchestrate predictive project delivery for large-scale initiatives. Such a combination helps detect risks early, compare plans with actual progress in real time, and communicate emerging issues clearly to both executive and technical audiences. This ability to translate complex technical data into strategic action is especially valuable for multi-stakeholder programs like the Giant Sea Wall, where rapid scale-up must be matched with precision and accountability

When implementation begins, AI tools can also function as dynamic project control systems. They continuously monitor real-time progress, compare it against planned baselines, and flag variances early. While scenario simulation is not a silver bullet, the ability to regularly test and adjust plans in response to field data and shifting constraints can help to support greater agility in implementation. This capability is especially important when multiple pilot sections are concurrently underway, each with different contractors, challenges, and environmental contexts along the coastline. Scenario testing is best seen as one tool in a broader AI-supported workflow that enables faster coordination, smarter trade-offs, and more confident delivery.

Globally, we have observed the engineering and construction sector to be adopting generative AI (GenAI) tools to help improve its processes, achieve cost efficiencies, and enhance construction performance and safety (see Table 8) . In the context of sea walls specifically, we have also witnessed the use of AI in the development of the proposed tidal lagoon sea wall in Swansea Bay, UK.

In this example, the UK Department of Energy & Climate Change had engaged academic and technology partners to empirically estimate the project's construction time and cost using a reference class forecasting approach with AI. This involved benchmarking against large-scale sea walls and flood protection projects in the Netherlands, UK, and globally. AI-supported tools helped clarify delivery risks and enabled decision-makers to assess whether the proposed solution was financially and technically viable. The result was a more evidence-based dialogue about trade-offs, leading to more informed policy outcomes.

Table 8: Value realisation, use cases, and application of GenAI

Value realisation	Use case	Application
Offshore	Generation of optimised site plans	Develop site plans by automating certain aspects of the design process
	Project scheduling	Optimise schedule by analysing resource availability and various other constraints
	Content summarisation	Extract key information from technical documents and synthesise field reports
Design and engineering adeptness	Efficient building/construction automation systems	Recommend the design of efficient and sustainable building/construction automation systems
	Generation design	Create new 3D product design based on inputs and constraints to visualise multiple alternatives of a particular industrial component
	Generative material design	Utilise scientific principles to create new materials with optimised properties
Operational efficiency	Process optimisation	Organise/reorganise project activities based on status and notify or prepare a contingency plan
	Smart summaries for drone surveys	Summarise a large volume of drone footage and enable querying for various applications
Enhanced safety, risk management, and compliance	Quality assurance	Generate synthetic images required to train machines and generate preventive algorithms aligned with automating site and quality inspection processes
	Ensuring compliance	Automate compliance checking of building/ construction designs against local building/ construction codes and regulations

Source: Deloitte AI Institute.

Tailor solutions to local context

Evidence from global case studies suggest that giant sea wall projects have a significant and enduring effect on coastal communities, ecosystems, and infrastructure, including ports, canals, rivers, pipelines, and cables. Adapting to these new conditions requires decades of transformation and substantial financial investment. Due to their scale and impact, such projects are often controversial, sparking intense debates among diverse stakeholders, including local communities, the private sector, NGOs, and government bodies. To mitigate these impacts, any large-scale sea wall initiative should incorporate adequate additional measures to enhance its overall benefits.

Constructing a giant sea wall along the entire North Java coastline also raises concerns from a cost-benefit standpoint, as more affordable protective measures could be applied at several locations. Alternative solutions may yield greater benefits for local communities, especially those reliant on coastal fisheries and aquaculture. Solutions could also made more sustainable through the incorporation of nature-based approaches, such as mangrove restoration combined with an updated sea dyke.

Therefore, we believe the best coastal strategy for Indonesia is one that is tailored to fit the characteristics of its regions, in the form of variations of the Go Forward, Defend, and Restructure strategies. We recommend developing a multi-criteria decision support tool to match local contexts with the most suitable strategy type, which an approach we have observed to be effective in the UK and Netherlands with their adaptive pathway planning processes.

In this report, we have laid out a high-level map that can be leveraged to map local coastal contexts to the appropriate strategies. Implementing these strategies, however, should be done one step at a time. Specifically, rather than aim for a Giant Sea Wall to be erected along the entire North Java coastline, it may be wiser to pursue a Smart Coastal Development strategy, one that balances protection, adaptability, and sustainability to minimise costs and environmental impacts.

This approach is aligned with global shifts from monolithic defences to hybrid, flexible systems, which are best illustrated in Japan's variable-height walls and 'building with nature' initiatives in the Netherlands. In any case, it is pertinent to start implementing the variety of concepts now sooner, rather than later, to gain hands-on experience on the different strategies and create an organisational structure to support the subsequent scaling of these solutions across the entire North Java coastline.

Regions implementing a Go Forward strategy, in particular, should focus on developing a narrative for offshore sea walls that goes beyond safety and flood protection to also include economic development, regional renewal, connectivity, and job creation aspects. This will help to shift the conversation from environmental trade-offs to long-term value, and strengthen the investment case by highlighting the potential for new business opportunities and economic returns. It may take time for the community most affected by the offshore sea walls, such as fishers, to accept the narrative, but as economic development progresses and public spaces are rebuilt, the presence of the sea walls may in fact create a welcoming environment.

Nevertheless, regardless of the design choice, social equity and community acceptance must be front and centre of the Giant Sea Wall project. Drawing on the lessons learned from Jakarta's previous reclamation projects, it is critical to ensure that residents and fishing communities are actively engaged in the relevant design, implementation, and resettlement decisions.

Build with legitimacy

To effectively strategise and coordinate efforts to protect the North Java coastline, particularly in relation to the development of the Giant Sea Wall, a dedicated agency is essential. This agency should be empowered to report directly to the President and Coordinating Minister to drive quick decision-making, and be equipped with sufficient financial resources and professional talent to drive progress and overcome institutional challenges.

With the recent announcement of the North Java Sea Wall Authority to be established soon, the government should urgently issue a presidential regulation to propose a dedicated law that clearly defines the agency's mandate, governance structure, jurisdiction, and oversight mechanisms across the relevant regions. The agency must be given the authority to coordinate with key national ministries such as Public Works, Bappenas, Environment, and Finance, and with local governments. However, this mandate should not encroach on the legal authorities or responsibilities of existing agencies and local governments. Such overlaps would create friction and stall progress. The agency's role, instead, should be to facilitate and coordinate plans that deliver win–win solutions, particularly for local governments to ensure alignment with their regional development priorities.

Direct access to the President will also be critical in enabling the agency to overcome bureaucratic barriers and maintain momentum throughout implementation. A relevant example is the Committee for Acceleration of Priority Infrastructure Delivery (KPPIP), which reported directly to the President, had the authority to coordinate across sectors, and was allocated a budget to hire professionals to run its organisation. The KPPIP successfully facilitated the establishment of 210 National Strategic Projects by 2023.

Finance innovatively

With fiscal space under pressure at both the national (APBN) and regional (APBD) levels, traditional budgetary allocations alone may be insufficient to fund the program at the necessary pace and scale. A blended approach leveraging PPPs, including availability payment schemes for less economically feasible and less bankable segments, should be prioritised. In parallel, the application of Land Value Capture (LVC) mechanisms, such as betterment levies, joint development schemes, and special zoning incentives, can help mobilise local revenue streams tied to land appreciation resulting from public investment.

For offshore sea walls involving reclamation, PPPs and rights to manage and build – *Hak Pengelolaan Lahan* (HPL) and *Hak Guna Bangunan* (HGB) respectively – may also be explored for integrated real estate and infrastructure development. Such approaches enable cost recovery and enhances financial viability without compromising public ownership of the coastal defence asset.

Reclamation-related annual fees paid to the government should be determined through a structured and transparent process that reflects both the value of coastal and environmental protection and the anticipated economic benefits. Given the scale and complexity of these projects, collaboration with a diverse range of private sector stakeholders will be important to ensure that the benefits and costs are appropriately balanced. This collaborative approach can help align national policy objectives with long-term investment sustainability, fostering outcomes that are both economically viable and socially beneficial.

Instruments such as viability gap funding (VGF), contingent financing facilities, and partial risk guarantees could also be deployed to mitigate investor concerns. In addition, non-financial enablers, such as streamlined permitting processes, clear land acquisition frameworks, and integrated spatial planning, can significantly improve bankability and reduce execution risks. The Government should explore international climate finance options – such as adaptation funds through the Green Climate Fund or the Asian Development Bank – and consider issuing coastal resilience bonds to finance critical segments.

To improve the bankability of the Giant Sea Wall, the project must be positioned as both a coastal protection infrastructure and a catalyst for broader economic development. This requires bundling the sea wall with revenue-generating assets that can attract private investment. For example, inland looping toll roads that connect high-value urban and industrial centres – rather than sea-parallel corridors that merely replicate the Trans-Java Toll Road – could offer a more compelling economic rationale. Similarly, hydropower development in upstream catchment areas could supply stable, green energy to emerging economic zones, reinforcing both the investment rationale and the overall resilience of the program.

To support stakeholders in structuring and strengthening their investment case, Deloitte has developed the SHIELD framework as a basis for project preparation and investor engagement within the Giant Sea Wall development. Briefly, this framework comprises the following pillars (see Figure 13):

- **Strategic alignment (S):** Ensuring the project contributes to national goals of climate resilience, urban protection, and disaster risk reduction, while safeguarding high-value assets such as ports, industrial estates, and major cities;
- **Holistic engineering (H):** Emphasising technical designs that are resilient to sea-level rise and extreme weather, integrated with flood control systems (e.g. pumps, canals, retention basins), and supported by long-term operations and maintenance planning;
- **Institutional readiness (I):** Including clear project ownership (whether by government, SOEs, or a dedicated agency), progress on permitting and land acquisition, and alignment with regulatory instruments such as spatial planning regulation (RTRW) and environmental impact assessment (AMDAL);
- **Economic and financial viability (E):** Designing a financial model that prioritises revenue-generating components, such as inland toll roads, upstream hydropower, or monetisable reclaimed land, with robust projections of internal rate of return (IRR), net present value (NPV), and payback periods. It should also incorporate lifecycle cost estimates (e.g., capital expenditure, operating expenditure), value capture opportunities, and clearly structured public support instruments such as viability gap funding (VGF), guarantees, or long-term land rights. Focusing on this pillar enables the project to transition from a government-driven protective asset to a commercially viable investment platform. Indeed, while all pillars are important, particular emphasis should be placed on this one, as it directly determines the project's ability to attract private capital;
- **Leverage and financing structure (L):** Assessing the availability of diverse funding sources, from state budgets and multilateral institutions to climate finance and private investment, along with mechanisms for blended finance and risk mitigation (e.g. guarantees, insurance, fiscal backstops); and
- **Delivery capability (D):** Focusing on strong implementation governance, including experienced project executors, phased construction planning, environmental, social and governance (ESG) compliance, and community participation.

Figure 13 : Deloitte's SHIELD financing framework

S – 1 Strategic Reliance	H – 2 Holistic Technical Design	I – 3 Institution Readiness	E – 4 Economic & Financial Viability	L – 5 Leverage & Financing Structure	D – 6 De-risked Delivery and Governance
How is the **North Java coastline project aligned with national priorities** such as climate resilience, disaster risk reduction, and coastal protection?	Do the **technology design** and **engineering strategies** ensure the **project is viable** given the **coastal conditions and physical challenges** of North Java?	Has the **Sea Wall Authority** been formally established with full powers over **land**, **permitting**, and **contracting**?	Does the project offer **returns** (IRR, NPV) that **meet investor expectations?**	What **funding schemes** (e.g. PPP, e.g., APBN, climate funds, MDBs, blended finance, Government bonds, land value capture, equity, multilateral support) offer **attractive returns** for investors?	Is there a **clear deliver structure** with a capable lead agency and PMO to support execution and coordination?
Does it **protect high-value economic assets** like ports, industrial zones, and urban settlements?	Does **the project integrate with upstream/ downstream systems,** such as pumping station, piping, drainage canals, and river management?	What are the **progress** for the **permits**, **land acquisitions**, and **spatial planning approvals** (e.g., RT/RW, AMDAL) and are they on track?	Are **revenue sources** (e.g., lease income, reclamation rights, or co-investment zone) **reliable** and **sustainable** for long-term cash flow?	Which funding scheme is most suitable to ensure a **bankable ROI** while **balancing public** and **private interests**?	Have **major delivery risks** been identified and mitigated through practical strategies like phasing, packaging, or community engagement?
How can the project design **unlock broader potential economic values such as aquaculture, fisheries, tourisms,** and **logistics**?	Are **long-term operability and maintenance plans defined** to ensure sustainable delivery?	Are the roles of **government, ministries, SOEs** and **regional bodies** clearly defined to **avoid overlapping** mandates and project execution delays?	Are the **CAPEX**, **OPEX**, and **lifecycle costs** clearly **estimated** and **optimised**?	Have the **potential investors** been engaged early to **assess interest**, **return expectation**, and **risk appetite**?	Is there a **governance mechanism** in place to **manage disputes**, **cost escalations**, and **policy shifts** across the project lifecycle?

Plan holistically

Given the extensive studies already conducted, Indonesia should develop a national coastal protection masterplan that consolidates and updates past technical and policy documents (e.g., NCICD 2016 and 2020) into a unified long-term strategy. This plan must align with national priorities outlined in RPJMN 2025–2029, integrate regional spatial planning (RTRW), and reflect the nation's climate adaptation commitments.

Beyond physical infrastructure, the masterplan should address land use, environmental sustainability, economic zones, and social issues such as resettlement and access to coastal livelihoods. It must define the alignment and typology of sea walls (open or closed), identify areas for reclamation and urban growth, incorporate green buffers like mangroves, and allocate space for integrated utilities, transport, and renewable energy. This should be underpinned by hazard modelling that considers land subsidence, sea-level rise, extreme weather, and tidal flooding to ensure adaptive and resilient planning. Embedding adaptive pathways planning with clear decision points and scenario triggers can help to ensure infrastructure decisions remain flexible as conditions evolve.

As coastal development spans multiple jurisdictions, the masterplan must guide and align provincial and local planning, especially in priority areas such as Jakarta, Bekasi, Karawang, Semarang, and Surabaya. A key enabler is the issuance of a Special Presidential Regulation or dedicated national law to provide legal authority for development, financing, land acquisition, and governance. This regulation should designate the sea wall as National Strategic Infrastructure, enabling coordinated implementation across national ministries and agencies – such as the Ministry of Public Works and Housing (PUPR), Ministry of Agrarian and Spatial Planning (ATR), National Land Agency (BPN), Ministry of National Development Planning (BAPPENAS), Ministry of Finance (Kemenkeu) – as well as local governments.

Given the scale and complexity of the initiative, a phased approach is essential. Jakarta has been identified as the logical starting point for Giant Sea Wall implementation, building on the momentum of the ongoing NCICD programme. As the capital and one of the most vulnerable coastal cities, Jakarta offers both urgency and opportunity for demonstrating impact.

Taking the first step towards implementation in Jakarta

The Jakarta–Bekasi–Tangerang (JaBeTa) Bay development has been integrated into the NCICD Master Plan and mandated by President Prabowo Subianto for budget allocation through the DKI Jakarta Regional Budget (APBD). To minimise public resistance and avoid missed opportunities for broader impact, JaBeTa Bay requires a coordinated, future-ready coastal development strategy. The following steps outline key actions to build a robust strategy for the area.

Master plan expansion

The Giant Sea Wall master plan should be developed in close collaboration with key stakeholders, and expanded to include the underexplored eastern section of JaBeTa Bay. To serve as a foundation for rapid decision-making and broad endorsement, this expansion should build on existing studies to identify optimal layouts that deliver maximum benefits with minimal impact.

Master plan detailing

The master plan should encompass key elements such as the sea wall, port development, land use, fisheries, and environmental mitigation. While further studies may proceed separately, they must align with the plan. Once finalised, the plan will guide alignment, reservoir use, and financing. This will lead into a one-year front-end engineering and design (FEED) phase, including detailed surveys and feasibility studies, enabling a final investment decision (FID) and contract preparation. Construction could begin within three years of this process.

Stakeholder engagement

Engaging stakeholders during the plan development process is crucial, especially given the offshore sea wall's history of discord and criticism. Early dialogue will help ensure that stakeholder interests are considered and may secure broader endorsement. The Final Master Plan will serve as the framework for transforming the bay.

International financing

Leveraging international financing organisations could encourage the development of plans that meet global standards and facilitate future funding. Several organisations have expressed interest in supporting the Indonesian government's development of the offshore sea wall, though many advocate for a holistic, transformative approach rather than a purely structural solution. This aligns with the priorities of DKI Jakarta Governor Pramono Anung and Deputy Governor Rano Karno, who plan to allocate the 2025 APBD to tackle flooding issues in the long term, focusing in normalizing the Ciliwung river, purchase pumps, and land consolidation.[59]

Packaging with other bankable projects

To enhance bankability, the sea wall can be bundled with commercially viable projects such as toll roads. The government can revisit this bundling approach, as recommended by the Dutch Expert Team and the Phase V Program/ Project Management Unit (PMU V) of NCICD, who proposed that Phase B of the open sea dyke be procured through a design-build (DB) model under a PPP with a design, build, finance, operate, maintain, transfer (DBFOMT) contract structure, as outlined in Ministerial Decree No. 112/KPTS/2022. Payments would be milestone-based, with parallel land development led by a state-owned enterprise to support fiscal recovery.

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Conclusion

The Giant Sea Wall holds significant potential to protect the coastlines in the north of Java, Indonesia's most vital economic corridor. However, we believe that only a tailored approach to its development will be effective. Global case studies show that continuous giant sea walls often come with substantial impacts on communities, ecosystems, and infrastructure – and high financial cost.

This report explores alternative coastal protection strategies to support a tailored approach for each region in along the North Java coastline. The Go Forward strategy, where the Giant Sea Wall fits, emphasises offshore sea walls that blend grey and green infrastructure, and is best suited for dense urban hubs along the coastline with high economic activity. In less dense or economically active areas, more appropriate approaches include the Defend strategy (onshore or nearshore sea walls) and the Restructure strategy (relocating assets and communities inland).

Where the Go Forward strategy is most applicable – in areas such as Jakarta, Semarang, and Pekalongan – the rationale for the Giant Sea Wall must extend beyond coastal protection to a broader narrative that highlights its role in safeguarding Indonesia's economic heartland and improving livelihoods for affected communities. This narrative must be clearly communicated to secure public support.

To ensure progress on the ground, a dedicated Sea Wall Authority must also be mobilised immediately. Much needs to be done – quickly and accurately – from developing the masterplan and selecting bankable projects, to managing the complex coordination between national and local governments and coastal communities.

Acting now, and wisely, is critical. Despite the immense challenge, the potential reward is substantial. We remain optimistic about a bright future for North Java, enabled by a tailored and strategic implementation of the Giant Sea Wall.

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Appendix

National Capital Integrated Coastal Development (NCICD)

Indonesia's NCICD-II (2020) strategy, also referred to as the Integrated Flood Safety Plan 2020 (IFSP 2020) aims to protect Jakarta from coastal flooding, land subsidence, and sea-level rise. It comprises three stages of flood defence:

- **Stage A:** Immediate reinforcements to existing coastal defence system on the north coast of Jakarta, including strengthening dykes and upgrading pumping and drainage systems;
- **Stage B:** Construction of an outer sea dyke in the west (Tangerang–Jakarta) to manage storm surges and high tides in areas with relatively stable land; and
- **Stage C:** Construction of an outer giant sea wall in the east (Jakarta–Bekasi) that will mirror Stage B, with a part of the sea wall allocated to the Tangerang-Bekasi toll road.

In 2020, the project is led by DKI Jakarta Provincial Government and PUPR under MoU of implementation synergy of Stage A with total length of ~46km (built in 2015-2019), and the remaining of ~33 km (11 km under PUPR, and 22 km under Pemprov DKI Jakarta).[60]

Project rationale

The project aims to safeguard Jakarta's economic and political core, protect millions of residents from coastal hazards, and support long-term urban resilience and climate adaptation across North Java.

Project organisation

Stage A (39 km)[61] of the project was established in 2022 under the Decree of the Minister of Public Works and Housing No. 112/KPTS/M/2022, which laid out the management of this project by three Project Management Units (PMU) under PUPR and a PMU secretariat comprising three divisions, namely PMU I (Program and Planning Division); PMU II (Sea Wall Construction, Flood Control, and Raw Water Division); and PMU III (Sanitation and Drinking Water Development Division). The PMU secretariat collaborates with representatives from JICA, the Netherlands, and South Korea.

Project financing

Financing of Stage A will be shared between the national and local governments. DKI Jakarta is assigned to build 22 km which ~8 kilometre has completed as of March 2025[62] which financed through single year and multi years of DKI Jakarta regional budget (APBD). This division reflects the project's dual status as both a national strategic initiative and a regional urban resilience priority.

Beyond direct government financing, the project also receives broader support from both domestic and international stakeholders. Private investors, the DKI Provincial Government, and the national government will contribute to the broader NCICD project, which is estimated to cost around US$8-10 billion for the sea wall from Tangerang to Bekasi, including a bridge over the Tanjung Priok Port. The exact financing breakdown between these parties remains under negotiation, particularly as technical integration with other major infrastructure, such as Jakarta's Outer Ring Roads and mass rapid transit, is still being studied.

Significant international assistance has been provided by the Dutch government, which funded the master planning of NCICS-I and II and preliminary feasibility studies through its Official Development Assistance (ODA), totalling €11.4 million (comprising €3.9 million for the master plan and €7.5 million for the feasibility study). Additional funding came via the Partners-for-Water program, led by a consortium that includes Haskoning and Witteveen+Bos.

Total projected government investment stands at Rp68 trillion, including capital expenditure for the sea dyke and VGF for toll road development. The toll road component is being implemented through a DBFOMT scheme under a PPP arrangement. Revenue streams are expected from toll road user fees, VGF, and milestone payments. Between 2022 and 2026, the project is expected to generate Rp128 trillion in returns from dividends and equity withdrawals, resulting in a positive fiscal impact of approximately Rp71 trillion. State-owned enterprises (BUMN) will manage integrated land development along the dyke corridor, using reclaimed land for mixed-use urban expansion – reinforcing both economic viability and long-term resilience for Jakarta's coastal communities.

Project execution challenges

The 'Save the Jakarta Bay Coalition', which has brought together fishermen and other impacted parties since 2014, wrote two letters to Dutch Prime Minister Mark Rutte in 2016 expressing concerns about the NCICD and requesting that the Netherlands put pressure on the Indonesian government. However, no official statements were made regarding the situation, and residents and fishermen affected by the project were seemingly not adequately consulted.

Although the Giant Sea Wall is seen as an essential safeguard against land subsidence and tidal flooding in Jakarta, construction has caused significant social and environmental issues, particularly for coastal communities. Advocates have warned that damming the shoreline could increase flood risks for nearby smaller islands, and have raised unanswered questions about the management of redirected water.

Long-standing fishing villages have also been displaced as a result of the development, often without adequate resettlement options or meaningful engagement. In addition to forcing people from their homes, these evictions have disrupted local businesses, social networks, and direct access to the sea, which is many people's main source of income. Small-scale fishermen who rely on fair and open access to coastal resources have been further marginalised, as the construction of walls and artificial islands has restricted access to traditional fishing grounds and converted once-shared marine areas into spaces governed by the state or private interests.

Project impact and value generation

The NCICD has been reframed as a national priority that extends well beyond Jakarta, impacting five provinces: Banten, Jakarta, West Java, Central Java, and East Java. Rather than being treated as a conventional public works project, it is positioned as a long-term, adaptive infrastructure initiative. This shift has encouraged stronger inter-ministerial coordination, the establishment of a dedicated taskforce, and the formation of international partnerships to support both investment and knowledge exchange.

The project has also spurred broader discussions around integrated water resource management, urban planning, and coastal conservation. In addition to its protective functions, reclaimed sections of the NCICD have been transformed into public spaces that foster social cohesion and recreational activities, contributing to the well-being of coastal communities. Most importantly, the infrastructure provides critical protection for these communities against the increasing threat of sea level rise.

Lessons learned

The existing 13-kilometre sea dyke is difficult to upgrade due to its integration with residential areas, highlighting the need to address spatial constraints and relocation early. Offshore alignments along the 15-metre depth contour, as proposed in studies since 2009, will enable dual functions of flood protection and land reclamation. However, project bankability remains a challenge, with basic offshore dykes costing an estimated US$100-120 million per kilometre and requiring at least 50 hectares of reclamation per kilometre of sea wall to support financing. In areas such as West and Central Jakarta, this translates to a minimum of 1,500 hectares, with full development potentially taking 15 to 20 years based on current land absorption rates.

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List of abbreviations

AP	Availability Payment
APBD	*Anggaran Pendapatan dan Belanja Daerah*
APBN	*Anggaran Pendapatan dan Belanja Negara*
CAPEX	Capital Expenditure
CMEA	Coordinating Ministry for Economic Affairs
COD	Chemical Oxygen Demand
DBFM	Design-Build-Finance-Maintain
DEM	Digital Elevation Model
EFSI	European Fund for Strategic Investments
EIA	Environmental Impact Assessment
EIB	European Investment Bank
ICI	International Conference on Infrastructure
JCDS	Jakarta Coastal Defence Strategy
JICA	Japan International Cooperation Agency
K-Water	Korea Water Resources Corporation
LSD	*Lahan Sawah Dilindungi*
LVC	Land Value Capture
MSL	Mean Sea Level
NbS	Nature-based Solutions
NCICD	National Capital Integrated Coastal Development
ODA	Official Development Associate
OSD	Outer Sea Dyke
PJICDP	Pantura Java Integrated Coastal Development Plan
PMU	Project Management Unit
PPP	Public Private Partnership
RPJMN	*Rencana Pembangunan Jangka Menengah Nasional*
RTRW	*Rencana Tata Ruang Wilayah*
SDIA	Saemangeum Development and Investment Agency
SEZ	Special Economic Zones
SLR	Sea Level Rise
VGF	Viability Gap Funding

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