The Coastal Resilience Safety Factor:

A General Method for Coastal Design Under Deep Uncertainty, with a Vancouver Application

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This is a non-peer reviewed preprint copy, submitted to EarthArXiv. This paper is currently under peer review with Springer Nature, npj Climate Action.

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The author has no competing interests that might be perceived to influence the results and/or discussion reported in this paper.

Author Affiliation: None.

Funding Declaration: This research did not receive funding.

Abstract

Global sea level rise is accelerating, and a substantial portion of the coming rise is now committed regardless of future emissions; coastal cities must therefore shift from preventing the hazard to designing for it. That shift poses a question every other safety-critical discipline already answers in its own domain: how large a design margin a structure should carry when the load is deeply uncertain and the cost of failure is catastrophic. This paper reframes coastal design through the engineering logic of the safety factor and develops a Coastal Resilience Safety Factor (CRSF): a general, portable heuristic decision rule that sums the independent drivers of relative sea level rise demonstrable on a given coast and multiplies the uncertain among them, which in a two-driver case like Vancouver is the whole sum, by a margin scaled to the consequence of failure. The paper sets out the method in full: how any coastal jurisdiction populates the rule with its own drivers, a stopping rule that bounds additive summation, the discipline for setting and reviewing the consequence factor, the standardization of the planning horizon, and a governance cadence that separates annual review from event-driven revision so the standard stays current without unsettling the design basis a multi-decade capital programme depends on. The method is then put to its first application, Vancouver, among the most exposed Canadian municipalities: a low-lying shoreline carrying high-value land and regional lifeline infrastructure, compounded by its position above the Cascadia subduction zone, where a great earthquake could lower the land by a metre or more, adding coseismic subsidence to the climbing sea. Vancouver's technical study of the hazard is extensive, yet little attention has been paid to whether its adopted design standard is calibrated to the consequence of failure, or to what the gap will cost. For Vancouver the rule combines the climate-driven rise and the relative rise a Cascadia rupture could impose, both uncertain and upward, so that a coast whose dominant

driver is instead well-constrained or sea-level-lowering remains the awaited test of the method's full generality. The framework returns a defensible target near 3.4 m at central values and near 6 m for critical, long-lived assets, against the city's present flood construction level of roughly 1.6 m, which sits at the conservative corner of the range. Extrapolating the province's 2012 dike estimate to that standard places an all-protection response in the order of tens of billions of dollars, roughly CAD 25 to 50 billion for the moderate target, an upper bound on the most capital-intensive lever rather than the cost of the mixed strategy the paper recommends; even so, it remains a programme no municipal budget could absorb, and every year of delay raises both the price and the residual risk. Because such works require voter-approved borrowing under the Vancouver Charter, unfold over lead times measured in decades, and engage the authority of the Musqueam, Squamish, and Tsleil-Waututh Nations hold over their lands and waters, the paper concludes that the planning gap is one of calibration, financing, and governance rather than science, and that the prudent course and the affordable course are the same: to begin now.

Introduction

Global mean sea level is rising, and the rise is accelerating (Hamlington et al., 2024). The processes that drive it, the thermal expansion of a warming ocean and the loss of land ice, respond to heat already in the system, so a substantial portion of the coming rise is now committed regardless of future emissions; recent work finds that significant ice loss from parts of West Antarctica is effectively locked in over the decades ahead (Naughten et al., 2023). For the world's coastal cities this reframes the problem. The dominant climate response of the past three decades, mitigation in the sense climate policy uses the word, the reduction of greenhouse-gas emissions, remains essential but can no longer prevent the rise that coastal infrastructure must now be built to withstand. Attention turns, of necessity, to mitigation in the older engineering sense: the reduction of harm from a hazard that will arrive whatever is done about its cause. That is the domain of adaptation, and it is the domain of this paper.

Few Canadian cities are as exposed to that hazard as Vancouver. The city sits across a low-lying shoreline running from the Fraser River delta in the south to the industrial flats of Burrard Inlet in the north, with the dense reclaimed basin of False Creek between them; much of its most valuable land, its port and rail corridors, and the lifeline infrastructure on which the wider region depends sit at or near present sea level. Vancouver's exposure also carries a feature most coastal cities do not share. It lies above the Cascadia subduction zone, where a great earthquake would drop the land by a metre or more in minutes, adding coseismic subsidence to the slow climb of the sea and producing a relative sea level rise that can exceed the global-mean figure on which planning is usually based (Wang et al., 2021). The hazard the city must design for is therefore not the global average but a compounded local one.

The physical side of this hazard has been studied closely, and Vancouver's own technical work is substantial: the city has mapped its flood hazard across eleven zones, modelled the consequences, and produced a sophisticated suite of adaptation plans. What has received far less scrutiny is whether the design standard the city has actually adopted is calibrated to the hazard those studies describe, and what the distance between the two will cost. Vancouver builds new coastal works to a flood construction level of roughly 1.6 metres. Whether that figure is adequate, generous, or dangerously low cannot be judged against the hazard alone; it must be judged against the consequence of being wrong, which is the question an engineer designing any other safety-critical structure asks first. The economic implications of the answer, and the financial consequences of deferring it, have drawn correspondingly little attention next to the physical projections themselves. The gap in Vancouver's coastal planning, this paper argues, is not principally a gap in science. It is a gap in calibration, in financing, and in governance.

This paper sets out to close that gap on each of its three axes. It first reframes the coastal design question as engineers reframe every design question, through the logic of the safety factor: a structure is built not to the expected load but to the expected load multiplied by a margin proportionate to the cost of failure. Applying that logic to sea level, the paper develops a Coastal Resilience Safety Factor that combines the climate-driven rise, the relative rise a Cascadia rupture could impose, and a consequence-scaled multiplier, and shows that Vancouver's present standard sits not in the middle of the defensible range but at its lowest corner. It then turns to cost, extrapolating from the province's own adaptation estimate to the order-of-magnitude price of building to an adequate standard and weighing that against the compounding cost of delay. Finally it addresses timing and authority: when construction must begin if it is to stay ahead of the hazard, and how, under the Vancouver Charter, the authority to commit the city's own resources falls to the council Vancouver elects in 2026 and the voters who must approve its borrowing, an authority that sits alongside, and not above, that of the Nations over decisions affecting their lands and waters.

The argument proceeds in three movements. The first, Sections 1 through 7, is diagnostic: it sets out the observational evidence for acceleration, the physical drivers, the engineering principle of the safety factor and its application to coastal design, the compounding seismic and atmospheric hazards, and the distance between the standard those considerations imply and the standard the city has adopted and funded. The second, Sections 8 and 9, turns from diagnosis to response: how a large protective margin can be carried responsibly under deep uncertainty through monitored, adaptive pathways rather than a single wall, and why the Nations whose territory this is must hold authority over those decisions rather than merely advise them. The third, Section 10, draws the threads together, sets out the recommendations that follow, and states the conclusion the paper is built to support: that for a hazard this certain and this consequential, the prudent course and the affordable course are the same one, and both require beginning now. The method that is the paper's central contribution, the Coastal Resilience Safety Factor, is developed in Section 5: the sections before it build the consequence, the depth of uncertainty, and the compound local hazard the factor must answer, and the sections after it apply, cost, and govern the standard it returns.

Section 1: Observational Evidence and Acceleration

Global sea levels have risen measurably over the past three decades, but what is alarming is not the rise itself; it is the accelerating pace. Over the 31-year satellite altimeter record beginning in 1993, global mean sea level rose by approximately 111 millimetres, and the annual rate of rise more than doubled: from roughly 2.1 millimetres per year in the early 1990s to about 4.5 millimetres per year by 2023 (Hamlington et al., 2024); an independent synthesis of the same altimetry record reports the rate roughly doubling over the three decades to 2022, from about 2.3 to 4.7 millimetres per year (Cazenave & Moreira, 2022). More strikingly, 2024 alone saw a rate of 5.9 millimetres, higher than the predicted 4.3 millimetres for the year, driven by an unusual surge in thermal expansion of seawater as oceans warmed to record temperatures (National Aeronautics and Space Administration [NASA], 2025).

This acceleration matters because it undermines linear planning assumptions. Vancouver's current flood-mitigation framework anticipates sea level rise of approximately one metre by the year 2100 and fifty centimetres by mid-century (City of Vancouver, 2014b). These projections are anchored to smooth, predictable trajectories. But recent observed data suggest the trajectory is not smooth; it is steepening. A 2025 study led from Durham University found that even under the most optimistic emissions scenario (i.e., limiting global warming to 1.5 degrees Celsius), sea level rise is likely to accelerate to rates that are very difficult to adapt to, with the annual rate potentially reaching approximately one centimetre per year within the lifetimes of today's young people (Stokes et al., 2025). If that acceleration materializes, mid-century sea level rise could exceed Vancouver's fifty-centimetre baseline, and the full-century picture becomes far more uncertain.

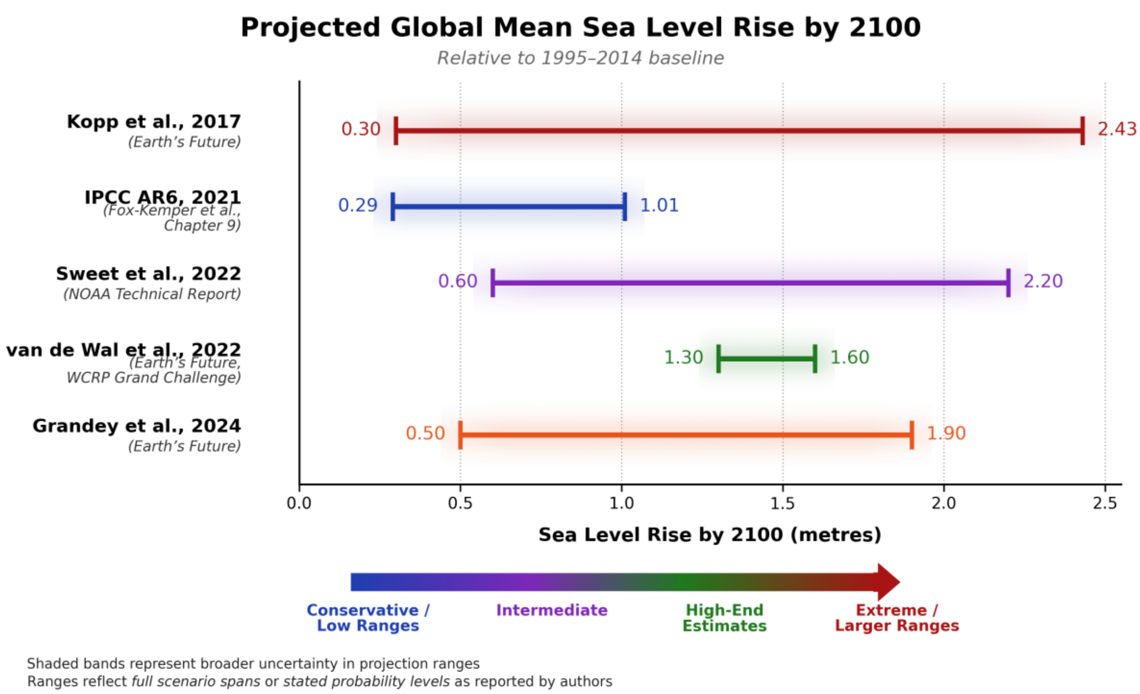
Projection Ranges to 2100

Across the peer-reviewed literature, projected global mean sea level rise by 2100 spans a wide envelope, from roughly 0.3 m at the low end to as much as 2.43 m at the high end, the upper figure being the 95th-percentile projection for 2100 under a high-emissions pathway once rapid Antarctic ice-sheet loss is admitted (Kopp et al., 2017), with several recent assessments placing the high-end plausible range at or above 1.5 m (see Figure 1). Vancouver's one-metre planning baseline therefore sits in the lower-middle of the scientific envelope and below the high-end estimates that practitioner-oriented and probabilistic studies now treat as decision-relevant. The upper portion of this envelope is corroborated by an independent line of evidence: a structured expert judgment study elicited from an international panel of ice-sheet specialists placed the 95th-percentile global total at approximately 2.38 m by 2100 under a high-emissions scenario, and its authors explicitly supported planning for twenty-first-century rise exceeding two metres (Bamber et al., 2019).

It bears emphasis that the IPCC AR6 likely range plotted in Figure 1 (0.29–1.01 m) represents only the 17th to 83rd percentile interval for processes assessed with at least medium confidence; the assessment states separately that, owing to deep uncertainty in ice-sheet processes, global mean sea level rise approaching 2 m by 2100 under a very high emissions scenario (SSP5-8.5) cannot be ruled out, a low-confidence, high-impact outcome that lies well beyond the plotted likely range and roughly double Vancouver's one-metre planning baseline (Fox-Kemper et al., 2021).

Figure 1

Projected Global Mean Sea Level Rise by 2100 Across Five Studies



Note. The figure compiles projected global mean sea level rise by 2100, relative to a 1995–2014 baseline, from five peer-reviewed sources spanning different methodological approaches. Each range represents a distinct type of projection: Kopp et al. (2017) report the full span from RCP2.6 to RCP8.5 scenarios; the IPCC AR6 range (Fox-Kemper et al., 2021) represents the likely (17th–83rd percentile) interval across SSP1-2.6 to SSP5-8.5; Sweet et al. (2022) present the full Low to Extreme scenario envelope; van de Wal et al. (2022) provide a high-end estimate developed for practitioner decision-making; and Grandey et al. (2024) report a very likely (5th–95th percentile) interval under high-emissions conditions. Colour indicates qualitative position on a conservative-to-extreme spectrum and is interpretive. Readers seeking detailed methodological justification for any range should consult the original papers. Figure created by the author.

Section 2: The Physics of Sea Level Rise

The Underlying Forcing: A Warming No Longer Bounded by 1.5 °C

The acceleration documented above does not originate in the ocean; it originates in the atmosphere, and the trajectory of atmospheric warming has now moved decisively past the threshold around which a generation of climate policy was organized. The year 2024 was the first full calendar year in which global mean surface temperature exceeded 1.5 °C above the pre-industrial baseline, reaching an anomaly of approximately 1.55 °C (World Meteorological Organization, 2025a). Because the Paris Agreement defines its limits as multi-decadal averages, the threshold has not been formally breached; but Bevacqua et al. (2025) demonstrate that, absent very stringent mitigation, a single year above 1.5 °C is itself the signal that the Earth has most probably already entered the twenty-year period whose average will reach that level, with the formal crossing falling near the midpoint of that window. The World Meteorological Organization (2025b) assigns roughly a 70% probability that the 2025 to 2029 average will exceed 1.5 °C. The target survives as an aspiration; as a forecast of the world that coastal infrastructure must actually be built for, it no longer describes reality. This bears directly on the present argument: Stokes et al. (2025) find that 1.5 °C is itself too high for long-term ice-sheet stability, so crossing it is not a marginal exceedance but an entry into the range in which the ice-sheet contribution to sea level rise becomes more dangerous, not less.

If 1.5 °C has effectively been passed, 2 °C is no longer the expected outcome but the optimistic one. The United Nations Environment Programme's most recent assessment concludes that full implementation of current national pledges would hold warming to roughly 2.3 to 2.5 °C this century, while the trajectory implied by policies actually in force points to approximately 2.8 °C (United Nations Environment Programme, 2025); the previous year's assessment placed the current-policy figure as high as 3.1 °C (United Nations Environment Programme, 2024). A 2024 survey of climate scientists found that nearly four in five respondents anticipate warming of at least 2.5 °C by 2100 (Ripple et al., 2024). The constraint here is not physical but political: holding warming to 2 °C would require cutting global emissions on the order of 42% by 2030, yet aggregate ambition has stagnated and emissions continue to rise. The gap between what governments have pledged and what they have delivered, and the further gap between those pledges and the Paris goals themselves, has not meaningfully narrowed. This conclusion does not rest on emissions accounting alone; the ocean's own response now points the same way. When recent observed sea-level acceleration is compared against the IPCC scenarios, its central value already tracks between the moderate-emissions RCP4.5 and high-emissions RCP8.5 pathways and sits above the broadly Paris-consistent RCP2.6, and the observed rate would have to slow for the world to return to that lower path (Wang et al., 2021). The short observational record means no single scenario can yet be statistically excluded, but the direction of travel matches what the emissions trajectory implies: away from the optimistic case.

More troubling than insufficient ambition is active reversal by the largest actors. On 20 January 2025 the United States initiated its second withdrawal from the Paris Agreement through Executive Order 14162, moved to rescind its international climate-finance commitments, and positioned the withdrawal to take formal effect in January 2026, leaving the world's largest historical emitter among the few states outside the agreement (Congressional Research Service, 2025); the administration has paired this with public skepticism toward the scientific consensus on anthropogenic warming. For a coastal planner the implication is concrete. The forcing that drives the sea level rise this paper addresses is set by global emissions; those emissions are largely governed by political will; and that will, among the largest emitters, is now weakening rather than strengthening. A planning framework anchored to a moderate-emissions scenario is therefore anchored to the more hopeful tail of a distribution whose political center of gravity is sliding toward the worse end. This compounds the calibration problem developed later in this paper: it is not only that the physical tail is fat and poorly constrained, but that the policy trajectory is steering into it. A margin calibrated for a 1.5 °C world, set during the years when that target still seemed reachable, is increasingly a margin calibrated for a future the world is no longer on course to inhabit.

To understand why this acceleration is occurring, the mechanisms driving it must be examined. Global sea level rises through two primary processes: thermal expansion of seawater and the addition of water from melting land-based ice, namely glaciers and ice sheets.

Thermal Expansion

Thermal expansion is straightforward physics. Water, like most liquids and solids, expands as it warms. When the ocean absorbs heat from the warming atmosphere, a direct consequence of greenhouse gas concentrations trapping outgoing radiation, its volume increases. The more heat absorbed, the greater the expansion. In 2024, thermal expansion accounted for approximately two-thirds of observed sea level rise, a striking reversal from the historical pattern in which melting ice dominated (NASA, 2025). This shift reflects the exceptional ocean temperatures recorded that year, with global oceans reaching their warmest levels in three decades of satellite records. As atmospheric temperatures continue to rise due to continued greenhouse gas emissions, oceans will absorb more heat, and thermal expansion will remain a significant driver of future sea level rise.

Ice Sheet Dynamics

The second mechanism is the addition of water from melting ice sheets and glaciers. The Greenland Ice Sheet, if it melted entirely, would raise global sea levels by approximately seven metres. The Antarctic Ice Sheet holds vastly more, on the order of fifty-eight metres of sea level equivalent in total, but the near-term concern is concentrated in the West Antarctic Ice Sheet, which contains roughly five metres, of which the marine-based portion most vulnerable to rapid collapse represents about three metres (Stokes et al., 2025). These are slow-moving systems under normal conditions, but climate change can trigger tipping points that accelerate ice loss through self-reinforcing feedback mechanisms.

For example, as ice sheets melt, their surface becomes darker as exposed rock and meltwater absorb more solar radiation than white ice. This darker surface absorbs more heat, which accelerates further melting. Similarly, warming ocean water intrudes beneath floating ice shelves, melting them from below and removing the mechanical “plug” that slows the ice sheet’s flow into the ocean. These feedback loops can create runaway processes in which initial warming triggers a cascade of effects that amplifies ice loss far beyond what would be expected from the warming alone.

The West Antarctic Ice Sheet is of particular concern. Much of it sits on bedrock that slopes downward toward the interior, a geometry that makes it vulnerable to a process called marine ice sheet instability. Once retreat begins, it can become self-sustaining: as the grounding line (where the ice sheet meets the ocean) retreats into deeper water, the ice becomes thicker at the grounding line, which increases the discharge of ice into the ocean. This positive feedback means that stopping the retreat becomes difficult even if temperatures stabilize. Recent modelling sharpens this concern. A comprehensive suite of regional ocean-model projections finds that rapid warming of the Amundsen Sea, at roughly triple the historical rate, is likely committed over the twenty-first century, driving increased melting of the ice shelves that buttress the West Antarctic Ice Sheet, including in the regions most critical to its stability (Naughten et al., 2023). Once internal climate variability is accounted for, the mid-range emissions pathway and the most ambitious Paris targets prove statistically indistinguishable for this ocean warming over the century, with only the worst-case scenario diverging, and only after roughly 2045; mitigation now retains little power to prevent it. The authors do not couple their ocean model to an ice-sheet model and so cannot quantify the resulting rise, and they stress that the West Antarctic ice is one sector among several; but their conclusion is pointed, that the opportunity to preserve this ice sheet in its present-day state has probably passed and that planners should prepare for several metres of rise over the coming centuries. A complementary line of modelling extends the concern to the two largest ice shelves, the Filchner–Ronne and Ross, which presently sit in colder water. Forcing an ice-sheet model with an ensemble of ocean-model melt rates, Hill et al. (2024) find that once those cavities undergo a cold-to-warm regime shift, grounding-line retreat in several places becomes irreversible: restoring present-day ocean conditions, or even cutting melt rates well below them, no longer halts it. This bears directly on the buttressing logic above, since it shows the self-sustaining retreat is not merely difficult to stop but, past a threshold, beyond recall. The melt rates imposed represent plausible high-end conditions of the coming centuries rather than this one, and the retreat is regionally irreversible rather than a runaway collapse of the entire ice sheet; but within those bounds the result holds across melt parameterizations. Critically, this is a source of deep uncertainty: the timing and pace of such retreat are poorly constrained, and the resulting probability distributions are themselves uncertain, a point that becomes decisive for how planners should respond.

Section 3: Engineering Safety Factors and Designed Uncertainty

Across multiple engineering disciplines, a consistent principle governs the design of critical infrastructure: systems are not built to the edge of expected performance. Instead, they are built with margins, factors that account for uncertainty, unexpected loading, and the consequences of failure.

In bridge engineering, structures are designed with safety factors that, in aggregate, fall in the range of roughly 1.5 to 2.5 times the maximum expected load. (Modern codes distribute this across separate load and resistance factors rather than applying a single global multiplier, but the net effect is a comparable margin.) The margin varies with consequence: a small pedestrian footbridge sits at the lower end, while a major urban highway bridge whose failure could kill hundreds is built with more conservatism.

In electrical engineering, the principle extends to transient peaks and unexpected demand surges. Power equipment is designed not merely to handle expected continuous loads, but to absorb spikes that exceed normal operating conditions. A transformer with a continuous rating near 100 MVA typically carries a short-term overload capability well above that rating, again a margin on the order of 1.5 to 2.0, before insulation or thermal limits are threatened.

Aircraft design is often described as the most safety-critical discipline, and it repays closer attention, because its margin is structured in an instructive way. Airworthiness standards do not rely on a single enormous multiplier. They require structures to withstand an ultimate load of 1.5 times the limit load, the maximum load expected in service, without failure (14 C.F.R. § 25.303, 2024). That explicit factor of safety is, perhaps surprisingly, modest. What makes aviation extraordinarily safe is not the size of that number but the layering around it: a conservative definition of the limit load itself, structural redundancy, damage-tolerant design, fatigue testing to several times the expected service life, and mandatory inspection intervals that re-verify the margin throughout the aircraft's life. The protection is distributed across many mechanisms and continually monitored, rather than banked in one large factor at the design stage.

The common principle is this: engineers scale their margins not only to expected conditions but to the worst plausible conditions and the magnitude of consequence; and, in the most demanding cases, they build the margin as a layered, monitored, and revisable system rather than a single fixed number. The more catastrophic a failure would be, the further back from the edge they build, and the more redundantly they build it.

Section 4: Compounding Hazards and Coastal Complexity

Coastal flood systems, unlike engineered structures with defined loading conditions, face natural variability that compounds in ways difficult to predict or model. Sea level at any given moment is not a simple number; it is the result of multiple interacting systems operating simultaneously.

The baseline sea level itself is rising due to thermal expansion and ice melt, the mechanisms described above. But superimposed on that rising baseline are tidal cycles driven by the gravitational pull of the moon and sun. King tides, the highest tides of the lunar month, occurring when the moon and sun align to reinforce each other's gravitational pull, already push water significantly higher than average high tides. Atmospheric pressure systems create additional variation: low-pressure storm systems allow the ocean surface to bulge upward, while high-pressure systems depress it. Wind-driven storm surge, where strong winds push water toward shore, can add fifty centimetres to a metre or more to local water levels during major storms.

These hazards do not add linearly. A king tide coinciding with a major storm surge, occurring during a period of elevated baseline sea level, creates compound extremes far exceeding what any single factor would produce. This is not a peculiarity of the local setting but the general rule at the coast. A systematic review of 279 studies finds that coastal flood drivers frequently combine to produce disproportionately extreme impacts even when no single driver is itself extreme, and that conventional univariate assessment, by treating the drivers in isolation, systematically understates the resulting risk (Green et al., 2025). That review further documents that on the west coast of North America the relevant drivers are statistically dependent rather than independent, with river discharge and rainfall each tending to be elevated alongside coastal water level during the winter storm season; for a low-lying region at the mouth of the Fraser, that dependence is the condition under which the compounding matters most, since the drivers are liable to arrive together rather than singly. Temperature anomalies in the ocean can intensify storms and change their tracks. Changing atmospheric circulation patterns, themselves a response to Arctic warming, are altering storm frequency and intensity in some regions. The system is not simple; it is a tangle of reinforcing feedbacks. The consequence for planning is that the relevant hazard is not a single rising number with a known spread, but a distribution of compound extremes whose shape, and especially whose tail, is itself uncertain.

Section 5: The Engineering Principle Applied to Coastal Planning

If engineering ethics and safety practice are scaled according to both uncertainty and consequence, a fundamental question emerges: what margin should govern coastal flood planning when the stakes are this large?

The consequences of inadequate coastal protection are not measured in the failure of a single structure, but in the fate of entire cities and regions. Flooding in a major coastal metropolis like Vancouver could result in hundreds of billions of dollars in property damage, the displacement of hundreds of thousands of people, loss of critical infrastructure, and loss of life. Scaled globally, inadequate sea level rise planning threatens hundreds of millions of people in coastal communities worldwide, trillions of dollars in infrastructure, and the stability of food and water systems that support billions. These are not loose figures. Correcting a long-standing positive bias in the satellite elevation data used for global exposure mapping, Kulp and Strauss (2019) estimate that under high emissions as many as roughly 630 million people could occupy land below annual flood levels by 2100, with about one billion already living within ten metres of the present high-tide line; even allowing for the bathtub model's tendency to overstate episodic-flood exposure, the order of magnitude is firmly established.

The Disanalogy, Met Head-On. A careful reader, particularly an engineering reviewer, will object that the analogy to bridges and aircraft is imperfect, and the objection is worth meeting directly. Engineering safety factors are applied to loads whose statistical distributions are reasonably well characterized: the variance is known, the tails are bounded, and the factor is calibrated against that known variance. Sea level rise driven by ice-sheet dynamics is a different species of uncertainty. It is deep rather than merely statistical: the relevant probability distributions are themselves poorly known (Kopp et al., 2019), and the tails may be "fat," populated by low-probability, high-consequence outcomes such as rapid ice-sheet collapse that resist precise quantification. This is not merely a theoretical worry. When an international panel of ice-sheet specialists was formally elicited through structured expert judgment, the resulting distribution carried a long upper tail: a 95th-percentile global total exceeding two metres by 2100 under high emissions, widening by a further 15% once interdependencies among ice-sheet processes were included (Bamber et al., 2019). That such elicitation is the method of choice here is itself telling; it is the tool reached for precisely when the distribution is too poorly constrained for a process model to pin down (Morgan & Henrion, 1990). Expert judgment has been criticized for limited traceability relative to physical models, yet the asymmetry of the error matters more than the method, because underestimating a catastrophic and partly irreversible tail is the costlier mistake. The point holds from the opposite direction as well: where the science is well constrained, it performs well. The near-term, broadly linear projections have been validated against satellite and tide-gauge observations, yet that validation explicitly does not extend to the late-century, non-linear ice-sheet acceleration that drives the dangerous tail (Wang et al., 2021). The deep uncertainty is thus not diffuse; it is concentrated exactly where the consequences are greatest. Part of it is, moreover, irreducible by policy: for the West Antarctic ice shelves over this century, internal climate variability has been found to outweigh the emissions scenario as a source of uncertainty, so even a known emissions pathway would leave the outcome substantially undetermined (Naughten et al., 2023). This disanalogy does not weaken the case for a generous margin; it strengthens it. When variance is known, one can in principle optimize a factor precisely. When the distribution itself is uncertain and the downside is catastrophic and partly irreversible, the rational response is a margin scaled to consequence, embedded in a decision framework that performs acceptably across the full range of plausible futures: the logic of robust decision-making and the precautionary principle, rather than the logic of a single computed multiplier.

Margin Is Not Free. It would be a mistake, however, to read “larger safety factor” as an unqualified good. Engineers do not build bridges to a safety factor of fifty, and the reason is instructive: margin is not free. Every increment of additional protection carries cost, and beyond some point the marginal dollar buys little additional safety. The engineering principle is therefore not “maximize the margin” but “optimize it against both consequence and cost.” Applied to a coastal city, this cuts in two directions. It justifies a margin well above routine practice where the consequence of failure is catastrophic, but it also concedes that fortification is not always the efficient answer. Past a certain level of sea level rise, the cost of ever-higher dikes, gates, and pumps may exceed the cost of accommodation or managed retreat from the most exposed areas. A defensible coastal strategy must therefore price the full menu of responses, protection, accommodation, advance (the reclamation of land from the sea), and retreat, rather than treating an ever-rising wall as the only lever (Kopp et al., 2019). The choice among those levers is not ecologically neutral. Coastal wetlands are themselves a form of protective infrastructure, attenuating waves and surge, and global modelling indicates that whether they survive rising seas depends primarily on accommodation space, the room available for them to migrate landward and to accrete sediment vertically (Schuerch et al., 2018). Hard defences foreclose that space: a wall fixes the shoreline and squeezes the marsh against it, so armouring can destroy the natural buffer in the act of building the artificial one. A worked example bears this out in economic terms: a holistic cost-benefit framework that priced beach recreation and ecosystem services, not just upland property, found coastal armouring the least publicly beneficial strategy over time precisely because it sacrifices the beach, while managed retreat undertaken sooner ranked as the best long-term option for protecting public-trust resources (Revell et al., 2021). The same modelling finds that, given sufficient accommodation space and sustained sediment supply, wetland area need not shrink and could even expand as the sea rises; both conditions are demanding, and on a sediment-regulated system such as the Fraser neither can be assumed, but together they identify nature-based accommodation as a lever with returns that hard fortification lacks. This is precisely the consequentialist accounting an honest safety-factor argument demands: the goal is the least-harm allocation of finite resources, not the maximal wall. How those levers should be sequenced, and who should bear the cost of choosing among them, is taken up in Section 8.

The Complete Hazard Picture: Sea Level Rise and Cascadia

Any honest accounting of the margin Vancouver should carry must include a hazard absent from most coastal-adaptation conversations and absent from most comparable jurisdictions: the geological one. The Pacific Northwest coastline, from northern California through Washington State to Vancouver Island, sits atop one of the world's most consequential tectonic boundaries, the Cascadia Subduction Zone, where the Juan de Fuca Plate converges with and slowly subducts beneath the North American Plate at a rate of approximately four centimetres per year. This region is part of the circum-Pacific Ring of Fire, an area of intense geological activity characterized by frequent earthquakes and volcanism. The geological record, preserved offshore in deep-sea turbidites and onshore in coastal sediments and intertidal wetlands, contains two classes of event that bear differently on this hazard. Over the past ten thousand years, the southern margin has ruptured in smaller, partial earthquakes on average roughly every two hundred and forty years, while the entire zone has broken in great, full-margin ruptures approaching magnitude nine only about nineteen times, at an average interval near five hundred and thirty years (Goldfinger et al., 2012; Walton et al., 2021). It is the full-margin rupture, not the more frequent partial one, that subsides the coastline of the Lower Mainland, so it is the full-margin event that bears on Vancouver. The most recent was a magnitude eight point seven to nine point two earthquake on January 26, 1700, documented through both Pacific

Northwest Indigenous oral traditions and Japanese records of the resulting tsunami; three hundred and twenty-four years have since elapsed, within the range the record displays but short of its average. Consistent with that history, at least seven great earthquakes are preserved in the buried-soil sequence of the last three thousand five hundred years, with intervals ranging widely, from roughly two hundred to nine hundred years (Atwater & Hemphill-Haley, 1997). The probability that bears on design is therefore the probability of the full-margin event: recent United States Geological Survey estimates place the chance of an approximately magnitude-nine Cascadia rupture at 10 to 15% within the next fifty years, rising toward one in four, roughly 19 to 28%, across the hundred-year design life of major coastal infrastructure (Wirth et al., 2025).

When projecting future coastal hazards for the Pacific Northwest, climate-driven sea level rise alone presents a significant but bounded challenge. Intergovernmental Panel on Climate Change localized relative sea-level rise projections indicate that sea levels along the Cascadia Subduction Zone could rise up to approximately zero point nine metres above 2023 baseline levels by the year 2100 under mid-range emissions scenarios. However, this projection captures only one component of the future coastal hazard. A critical variable often excluded from long-term sea level rise assessments is sudden, earthquake-driven land subsidence. That coseismic subsidence is not only modelled but observed: reconstructions from the most recent great rupture, in 1700, record coastal land-level drops of roughly 0.2 to 0.85 metres across six Oregon estuaries, derived from fossil foraminiferal assemblages preserved in the buried-soil record (Hawkes et al., 2011). Forward-looking modelling extends this established phenomenon to the next event. Research by Dura et al. (2025) demonstrates that the next great Cascadia Subduction Zone megathrust earthquake could cause between zero point five and two metres of instantaneous coastal subsidence across Washington, Oregon, and northern California. When this earthquake-driven subsidence is combined with the climate-driven sea level rise projected for 2100, the compound effect becomes catastrophic. If such an earthquake were to occur at or near 2100, floodplain areas along Cascadia estuaries could expand by one hundred and seventy to three hundred and seventy square kilometres, depending on subsidence magnitude, more than tripling the flood exposure of residents, infrastructure, and critical land uses compared to current conditions (Dura et al., 2025). The temporal synchronization of these two processes remains unknown, but the geological record makes their eventual co-occurrence not a question of if, but when. For the present argument, the implication is precise: Vancouver does not face only the climate hazard that drives policy elsewhere on the continent; it faces that hazard plus a credible, recurrent geological event that could, in a single moment, add one to two metres of effective relative sea level rise on top of whatever climate-driven rise has already accumulated. The margin a defensible policy must carry is therefore set by the joint distribution of both hazards, not by the climate hazard alone. That joint hazard has a fiscal signature as well as a physical one: when the province costed regional dike adaptation, the seismic reinforcement of three Fraser-frontage reaches in Richmond and Surrey alone was estimated to exceed CAD 80,000 per metre, a cost driven by the earthquake threat rather than by sea level rise itself (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2012).

The Real Planning Gap. With those qualifications in place, the gap comes into sharper focus. It is tempting to say that Vancouver plans to a bare single-point estimate, but that would not be fair, and the fairer version is the stronger one. The city does apply a margin and does plan adaptively: flood construction levels are set by adding roughly 0.6 metres of freeboard above the one-metre projection, the city explicitly acknowledges an upper scenario of up to 1.4 metres by 2100, and its framework is designed to be revisited as conditions evolve (City of Vancouver, 2014b, n.d.). The adaptive, monitored structure of this approach is, in fact, exactly right: it mirrors the layered, revisable margin that makes aviation safe. The city's Sea Level Rise Planning Framework makes this explicit, adopting a pathways approach that sets thresholds and drop-dead dates for each zone and pairs them with a local sea-level monitoring plan, so that decisions are anticipated and prioritized rather than all made now (City of Vancouver, 2018b).

The gap, then, is not the absence of a margin but its calibration. A freeboard on the order of 0.6 metres above a one-metre projection represents a multiplier of roughly 1.5 to 1.6, and freeboard must also absorb wave run-up and datum uncertainty, so the share genuinely available to cover sea-level-rise error is smaller still. That is the margin of a routine structure. It is the bridge factor, not the aircraft system. Yet the consequence of underestimation here is catastrophic, and it is compounded by deep, fat-tailed uncertainty of exactly the kind that, in any other safety-critical discipline, would call for a larger and more redundant margin rather than a smaller one. The planning gap, then, is not merely between what is observed and what is predicted. It is between the margin that engineering ethics would assign to a consequence of this magnitude under uncertainty of this depth, and the routine-grade margin that coastal planning currently implements.

Consequence and Scale in Practice: The New York Harbor Storm Surge Barrier

In 2022, the United States Army Corps of Engineers released the New York-New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study, proposing what it calls Alternative 3B: a roughly fifty-two-billion-dollar, multi-decadal commitment to protect the New York City metropolitan region from coastal storm surge through a combination of twelve storm surge barriers across the major waterways and more than forty miles of shore-based measures, including floodwalls, levees, berms, and elevated promenades along the Lower

Manhattan, East Harlem, and Jersey City shorelines (U.S. Army Corps of Engineers, 2022). The plan is tentatively selected, meaning it has advanced past conceptual phases and now awaits congressional authorization and funding. The case is instructive precisely because it demonstrates, in real federal policy, the principle this paper has been arguing: when consequence is catastrophic, the margin allocated is dramatically larger than routine engineering practice would suggest.

The consequence framing is explicit in the Army Corps analysis. Without the proposed protection, average annual damages to the region are projected at 5.1 billion dollars in 2030, rising to 13.7 billion dollars by 2100 under an intermediate sea level rise trajectory (U.S. Army Corps of Engineers, 2022). These are not marginal costs; aggregated over a fifty-to-eighty-year horizon, they represent hundreds of billions in losses. The region at risk includes much of Lower Manhattan, northern New Jersey, and adjacent waterfront communities, encompassing critical port infrastructure, refineries, residential neighbourhoods, and the financial centre of the eastern seaboard.

Yet the more telling part of the case, for the present argument, is what peer-reviewed analysis says about whether even this margin is sufficient. Independent of the 2022 plan and predating its selection, Chen, Orton, and Wahl (2020) modelled the gated harbour-barrier concept then under study, and found that gate closure frequency rises exponentially as seas rise, that closure duration lengthens, and that the probability of trapped river flooding behind closed gates increases over time. Their central finding is one of conditional adequacy. If seawalls are raised uniformly to the 2.13-metre flood-trigger elevation, the combined barrier-and-seawall system has a useful time horizon that could be as short as 2040, accounting for high-end sea level rise and operational forecast uncertainty, or as long as 2090 under central sea-level estimates with no forecast uncertainty (Chen et al., 2020). In other words, the lifespan of a fifty-two-billion-dollar federal protection system depends critically on which sea level rise scenario proves accurate, and on how conservatively its operations are managed. Under the worse plausible scenarios, much of the value of the investment is consumed within a generation.

This is the precise structure of deep uncertainty that this section has been describing. The Army Corps has not built to a single point estimate; it has committed to a large, layered, monitored system with explicit provisions for adaptive re-triggering as conditions evolve. Chen and colleagues conclude that costs and benefits will eventually need to be weighed neighbourhood by neighbourhood, and that in some cases retreat or other non-structural options may be preferable (Chen et al., 2020). The barrier, in other words, is not a final answer but a margin large enough to buy time for the next decisions to be made, while keeping the worst losses at bay. That is the engineering ethic this paper has argued for: a margin scaled to consequence, embedded in a framework that anticipates revision, and large enough to remain useful across a wide range of plausible futures.

The contrast with routine engineering practice is striking. A typical bridge is built to a safety factor on the order of 1.5 to 2.5; the New York system represents protection investment several times larger than annual expected damages, on the logic that the alternative, leaving the region undefended as seas rise and storms intensify, is catastrophically worse. The federal government has implicitly accepted the precautionary principle: under deep uncertainty about the future hazard, the rational response is a margin scaled to the worst plausible consequence, monitored adaptively, and revised as new information arrives. The peer-reviewed assessment is not that the barrier is the wrong choice; it is that even this scale of protection has a finite life under accelerating change, which is itself an argument for building it sooner rather than later, while options remain open.

The question for Vancouver is not whether such a margin is justified in principle. It is whether the city and the province have grasped that they face a more complex hazard than New York does. The Army Corps has committed a major coastal metropolis to a multi-decadal investment scaled to protect against accelerating sea level rise and storm surge, and even that scale of protection is judged by the best available analysis to have a contingent and bounded useful life. But New York does not face the geological hazard that confronts the Lower Mainland. The Cascadia Subduction Zone, documented above, poses a real and recurrent threat of major earthquake and the resulting coastal subsidence that would compound climate-driven sea level rise. A single great earthquake could instantaneously add one to two metres to effective relative sea level rise, on top of ongoing climate forcing. Under such a compound hazard, the margin Vancouver currently allocates, roughly 1.5 times a one-metre baseline, applied to a consequence of this magnitude, is not merely modest; it is conspicuously inadequate relative to both the science and what peer-reviewed analysis of comparable jurisdictions has concluded is required.

A Coastal Resilience Safety Factor for Vancouver

The preceding analysis identifies the gap as one of calibration: the city carries a routine multiplier against a consequence of the highest magnitude. The constructive question is what factor it should carry instead, and how that factor should be derived so that the method travels beyond Vancouver. This paper proposes a Coastal Resilience Safety Factor (CRSF): a regionally calculated design margin that scales the planning target to both the full set of documented local drivers of relative sea level change and the consequence of failure. The factor is built in two steps. First, the credible high-end projection to 2100 of every independent regional driver of relative sea level rise is summed into an aggregate hazard. Second, that aggregate is multiplied by a safety factor proportional to the consequence of failure and the depth of residual uncertainty, yielding the planning target:

$$\mathbf{T = (H_1 + H_2 + \ldots + H_n) \times S}$$

Here T is the planning target for relative sea level rise to 2100; H_1 through H_n are the region's independent hazard drivers, each quantified in metres; and S is a dimensionless safety factor, typically between 1.10 and 1.50. The form as displayed multiplies S across the whole bracket, which is exact when every driver is uncertain and acts upward, as Vancouver's two do; the general case, in which a well-constrained driver enters at its face value and a driver that lowers relative sea level enters as an offset outside the multiplier rather than within it, is treated with the consequence factor below. The drivers are summed rather than combined probabilistically because they are physically independent and act together, each contributing its full magnitude to relative sea level whatever the others do; this additive treatment is honest for the few drivers that dominate a coast, a limit made explicit below. For Vancouver the documented drivers are two, climate-driven rise and Cascadia coseismic subsidence, so the general expression reduces to:

$$\mathbf{T = (C + R) \times S}$$

Here C is the climate-driven sea level rise projected for this coast to 2100, ranging from roughly 0.90 m under localized mid-range projections to about 2.00 m at the ice-sheet-driven upper tail that recent assessments treat as decision-relevant (Fox-Kemper et al., 2021; Bamber et al., 2019); R is the relative rise from Cascadia coseismic subsidence, which recent modelling places between 0.50 and 2.00 m should the next great megathrust rupture within the planning horizon (Dura et al., 2025); and S is the safety factor, held between 1.10 and 1.50. The two drivers are genuinely additive: the first raises the sea surface, the second lowers the land, and relative sea level rises by their sum.

Populating H: A Framework for Regional Application. The factor derived for Vancouver rests on two drivers, but the method behind it is general. The bracketed term in the formula's general form is not confined to climate rise and Cascadia subsidence; it is the place to enter every process that moves relative sea level at the site in question. Relative sea level at a given coast is the superposition of three nested scales: a global-mean rise; regional departures from it, driven mainly by uneven ocean warming and circulation; and local processes, vertical land motion among them, that amplify or offset the result. It is this relative, local quantity, and not the global mean, that a coast must actually plan for (Cazenave & Moreira, 2022). A jurisdiction adopting the CRSF therefore begins not with Vancouver's figures but with its own, asking which drivers are scientifically demonstrable on its coast, in what magnitude, and in which direction.

The drivers that current science treats as measurable fall into a few families. The largest is climate-driven change: the thermal expansion of a warming ocean together with the added mass of melting glaciers and ice sheets, which is the dominant signal globally (Fox-Kemper et al., 2021). Vertical land motion from glacial isostatic adjustment, the slow response of the crust to the disappearance of the ice-age ice sheets, can act in either direction: land that lay beneath the ice is still rebounding upward and lowering relative sea level, as around the Gulf of Bothnia and Hudson Bay, while land on the collapsing peripheral forebulge is sinking and raising it. The United States Atlantic coast, including New York City, sits on such a forebulge and is subsiding by roughly one and a half millimetres a year on that account alone, so isostatic adjustment there compounds the climate signal rather than offsetting it (Buzzanga et al., 2023). Tectonic motion adds coseismic subsidence or uplift from earthquakes and slower strain from volcanism and plate boundaries; on this coast it is the Cascadia term already carried as R (Dura et al., 2025). Anthropogenic subsidence, the compaction of ground after the withdrawal of groundwater, oil, or gas, has produced some of the fastest relative rise on record in cities built over pumped aquifers and deltas. Sediment dynamics, the accretion or erosion worked by currents, river discharge, and the wave climate, can locally offset rise where deposition outpaces it or sharpen it where the supply of sediment is cut off, though usually over shorter and more reversible horizons than the other drivers. And shifts in ocean circulation and in the storm regime redistribute water between coasts and alter the surge heights against which a margin must finally hold.

Two qualifications keep the list disciplined. The regional variation in the climate term is not a separate driver to be added by hand: modern projections already account for the gravitational, rotational, and deformational redistribution of meltwater that makes the rise from a given loss of ice differ from one coast to another, so a jurisdiction should take its climate term from regionally downscaled projections rather than apply a global-mean figure (Fox-Kemper et al., 2021). Other processes that appear in the literature, the water held behind dams or drawn down from aquifers, submarine volcanism, the long-period orbital and deep-tectonic cycles, are either too small, too slow, or too local to bear on planning at a centennial horizon; they are best noted and set aside unless a specific local condition makes one of them consequential.

The discipline the framework asks for is completeness rather than selection. Every driver that is demonstrable and consequential at the planning horizon belongs in the sum, whether it raises the water or lowers it. Completeness is not symmetry, however: the asymmetry of error that justifies carrying a hazard at its upper credible value cuts the other way for a favourable term, since over-crediting a driver that lowers the water underbuilds exactly as under-counting one that raises it does. A subtractive term must therefore clear a higher evidentiary bar than an additive one, and a credit that is reversible or short in horizon, sediment accretion above all, is heavily discounted or excluded outright from a centennial target; only a lowering driver that is both well-constrained and persistent to 2100, such as post-glacial rebound on a rebounding coast, is carried, and then conservatively and as an offset outside the multiplier, on the basis the consequence-factor subsection sets out. So disciplined, a coast that is genuinely and durably rebounding may carry a smaller target than its neighbours, while a coast that is sinking even as it floods carries a larger one. The object is not to produce a single universal number but to oblige each jurisdiction to assemble, and to defend, the particular sum its own physical setting dictates, with the burden of proof falling most heavily on any term that would make the margin smaller.

Vancouver itself illustrates the discipline, and shows that the line between a local term and a regional one is drawn by geography rather than convenience. Beyond the two drivers carried in C and R, the city has a third potential term, ongoing vertical land motion, and completeness requires placing it rather than quietly deferring it. Most of the city sits on the bedrock uplands of the Burrard Peninsula, where that motion is small and any slow interseismic uplift would only make the estimate more conservative, so there it folds into C. But on the city's filled and soft ground, False Creek above all, the dense and high-value core this paper most cares about, sediment consolidation is a real local subsidence, and a Vancouver application carries it there as a site-specific third term rather than setting it aside. Its size must be read carefully: the rapid rates Mazzotti et al. (2009) record on artificial fill, three to eight millimetres a year, are initial rates that decay with a time constant of about twenty years, so the settlement is front-loaded and largely spent within two decades of placement, and a constant-rate projection to 2100 would overstate it. The live forward component therefore concentrates on recently placed or still-settling ground, where it can reach the order of a decimetre and is plainly decision-relevant against a climate term near a metre, and is small on long-established fill that has mostly consolidated already. What lies outside this paper's scope is a matter of geography, not category: the large and persistent natural-consolidation subsidence of the Fraser lowland itself, one to two millimetres a year across Richmond, Delta, and Lulu Island (Mazzotti et al., 2009), sits beyond the city on the regional delta and belongs to the regional coordination the paper calls for, not to a Vancouver-proper calculation.

Completeness in identifying the drivers is not licence to sum all of them at full magnitude, and the additive form has a domain beyond which it should not be pushed. Each driver enters at an upper-credible value, and the probability that several physically independent drivers all realize their high ends at once falls as their number grows; a sum of five or six such values therefore sits at a far more extreme joint percentile than any single term, and can describe a total no coherent estimate would endorse. Pushed that far, the additive heuristic has quietly become a probabilistic combination performed badly, by naive addition, which is the very thing the functional form is chosen not to be. The honest stopping rule is to carry the two or three drivers that dominate a coast additively, at their credible high ends, and, where further material drivers accumulate, to combine the driver distributions probabilistically rather than to keep stacking upper-bound point values. For Vancouver the question does not arise: the coast is governed by two dominant drivers, and the sum of two is where the additive form is at its most defensible. The instruction to populate H completely is thus an instruction to identify and weigh every consequential driver, not to inflate the target by adding many separate worst cases at once.

Because the science underlying each term improves continuously, the terms are not set once; but recalibration must be reconciled with the stability a multi-decade capital programme requires, and the two reconcile cleanly once review is separated from revision. The drivers and the resulting target should be reviewed annually by designated qualified staff and reported publicly, on a cadence aligned with the budget cycle so that each year's spending decisions are informed by the current state of the science. That annual review is a watchdog, not an automatic recalculation: its task is to report whether any input has moved, not to move the committed design basis every year. The design basis itself is revised only when a material input crosses the bounds already anticipated in the adaptation plan, a revised seismic probability, a documented acceleration in ice loss, a newly measured subsidence rate, whether that change is surfaced by the annual review or by evidence arriving between reviews; and the revision is then made deliberately, through the governance process that authorized the programme, on the same monitored-trigger logic that governs the advancement of protective layers in Section 8. The cadence of review is therefore annual and the cadence of revision is event-driven, and keeping the two distinct is what lets the standard stay current with the science without unsettling the design basis that financing, contracting, and a borrowing authorization depend on. A single calculation, of the kind this paper performs for Vancouver, is a valuable snapshot of the science and the hazard as they stand at one moment; the greater value to a coastal community lies in the series that successive reviews build over years and decades, which shows whether the drivers are moving as projected, whether the margin remains adequate, and whether the chosen adaptation path is keeping pace. Treated this way the safety factor is not a figure fixed once and consulted later but a standing instrument of adaptive coastal governance.

A last consideration is the horizon itself. This paper, like most of the literature and the assessments behind it, calculates to 2100, and that date is a convention rather than a limit: the ocean does not stop in 2100, and a margin sized only to it will look increasingly short-sighted as the century advances and projections to 2150 and beyond are firmed up. The horizon cannot, however, be left as a free dial, for two reasons the rest of the method makes binding. The first is comparability: because a longer horizon carries a larger climate term, two jurisdictions reporting against different horizons would produce targets that cannot be set side by side, which would defeat the common language the method is meant to give a province. The horizon must therefore be standardized; a jurisdiction reports its target against the common reference of 2100, so that targets remain comparable, and presents any longer-horizon calculation alongside that reference rather than in place of it. The second is integrity: the horizon for a particular work should be set by the service life of what is being built, so that a structure expected to stand into the twenty-second century is sized to a horizon that reaches it, and it should never be shortened to bring the target, and the cost, down. To choose a nearer horizon because it is cheaper is the same substitution of budget for consequence that this paper diagnoses in the present freeboard, merely relocated to the choice of date. The horizon is thus a standardized, reported, and justified parameter rather than a matter of fiscal convenience: stated explicitly, justified by the design life of the asset and the science available, reported with the target it produces, and advanced, when it advances, on a common schedule as the planning date itself draws nearer, so that jurisdictions move together rather than drifting apart.

Setting and Reviewing S: The Consequence Factor. The consequence factor S is the second of the formula's two operations, and it does different work from the sum. Where the bracket gathers what the hazard will physically do, S sets how large a margin the cost of being wrong deserves: it is a consequence-scaled premium on what is uncertain, held within a principled band whose ceiling is the aviation reference. This raises a question the two-driver Vancouver case did not. When every term in the bracket is both uncertain and upward, as C and R are, a single factor multiplies them all without ambiguity. But the general sum may hold terms of very different epistemic character: a near-deterministic term for glacial isostatic adjustment, among the best-constrained quantities in the field, can sit beside a deep-uncertainty ice-sheet tail, and a rebounding coast carries a term that is not only well-constrained but negative. Applied uniformly across such a sum, S would do two things it should not: inflate a term that carries almost no uncertainty to justify the premium, and, worse, multiply a favourable certain term so that good news erodes the very margin the factor exists to create. The convention that avoids both is simple. S multiplies the uncertain, upward drivers, the terms whose magnitude is in genuine doubt and whose underestimate carries the consequence; a well-constrained term may be carried at its face value rather than inflated; and a term that lowers relative sea level is in every case applied as an offset outside the multiplier, never inside it. For Vancouver the distinction is moot, since both drivers are uncertain and upward and S multiplies their whole sum, so the general form collapses to $T = (C + R) \times S$ exactly as written; it matters only for a coast that carries a well-constrained or sign-negative driver, and there it keeps the safety factor at its one proper task, enlarging the margin against what is uncertain and never trimming it on account of what is favourable and known. One qualification keeps this convention honest, and it is worth stating before a reviewer does. S bundles two things of different character: a premium against being wrong about an uncertain driver, and a set of allowances, for wave run-up, for datum, and for the processes outside the present models, that attach to the planning target itself rather than to anyone's uncertainty about which driver produced it. The rule just given is correct for the premium, since no cushion is owed against a quantity that is known, but it under-serves the target-attached allowances on a coast whose dominant driver is well-constrained, where multiplying them over only the small uncertain fraction would leave the run-up and datum allowance short of what the water level still demands. On such a coast those allowances are reattached to the full target rather than carried inside the driver-restricted multiplier. For Vancouver the point is again moot, since S multiplies essentially the whole hazard and the allowances ride the full target as a matter of course; it binds only the general case, and there the safe construction is to apply the uncertainty premium to the uncertain drivers and the level allowances to the target.

S also changes over time, but on different grounds and a different clock from the hazard sum. The recalibration set out above moves H against the science: a better ice-sheet model, an updated seismic probability, a newly measured subsidence rate. S is not an empirical quantity and must not move on those grounds. It encodes two things that are judged rather than measured: the consequence of failure, what stands behind the margin and how catastrophic and irreversible its loss would be, and the community's tolerance for that consequence. It should be reviewed when those change, when a basin like False Creek densifies, when a corridor becomes a designated lifeline, when an area is committed to managed retreat, or when a community's tolerance for that class of loss shifts, and not on the annual cadence that suits the science, since consequence and land use move over years and decades and an annual review of S would invite both churn and gaming. Two prohibitions keep the review honest. S must never be revised upward because the projections have worsened: that is the science, it belongs in H, and to let it raise S as well would count the same uncertainty twice, the error the heuristic defence below is built to avoid. And S must never be quietly trimmed under budget pressure while the targets are left untouched: that is precisely the substitution of cost for consequence this paper indicts in the present standard, and a review confined to documented, publicly reported changes in consequence or risk tolerance is what prevents it. Reduced consequence through committed retreat is the one principled route by which S may legitimately fall: retiring an area to managed retreat genuinely removes what stood behind the margin, a real reduction in the loss at stake, which is the opposite of a budget pressure that merely wishes the consequence smaller while it remains. That is why the retreat trigger can sit among the grounds for reviewing S without breaching the prohibition: the first lowers S because the consequence has actually fallen, the second would lower it though the consequence has not. Constrained in this way, a periodic review of S is not a loophole in the standard but the mechanism that keeps it consequence-calibrated as the city behind the margin changes.

Why a heuristic, and not a formal optimization. A reasonable objection is that the framework, as written, resembles a formula claiming to return the correct margin, and that a reviewer will ask why this expression rather than one of the established methods for deciding under uncertainty: expected-utility maximization, Bayesian updating, robust optimization, info-gap decision theory, real-options analysis, or multi-criteria decision analysis. The honest answer begins by stating what the Coastal Resilience Safety Factor is and is not. It is not an optimization, and it does not return the optimal margin; under deep uncertainty optimality is not merely hard to compute but undefined, since there is no agreed distribution over which to optimize. The CRSF is a heuristic design rule, in the specific and unembarrassed sense that the engineering factor of safety is a heuristic: a closed-form margin, calibrated to consequence, that underwrites bridges, airframes, and pressure vessels precisely because formal optimization over real-world uncertainty is intractable or fragile. The framework's claim is not that 3.4 m is correct but that a margin of that order is defensible, and that the routine-grade margin the city now carries is not. That is the claim a heuristic is entitled to make, and it is the only claim the uncertainty supports. The approach is not without precedent, and naming its nearest neighbour sharpens what is new here. Sharma et al. (2021) demonstrated a safety-factor approach to flood-sensitive infrastructure under deep uncertainty, adding empirically derived margins of roughly 1.4 to 1.7 to standard stormwater-pipe design to secure hydraulic reliability against a single deeply uncertain driver, intensifying extreme rainfall. The framework proposed here shares that logic but extends it on three axes: from a single pluvial driver to the additive combination of climate-driven rise and Cascadia coseismic subsidence; from a fixed reliability target to a margin scaled to the consequence of failure; and from a component-scale engineering choice to a city-scale question of financing and governance. That their independently derived factors fall in a comparable range, applied though they are to a different design quantity, is some assurance that the multiplier proposed here is of a defensible order rather than an arbitrary one.

The functional form is chosen, not arbitrary. The two operations in $T = (C + R) \times S$ do different work, and each is principled. The hazards are summed because they are physically additive: the sea surface rises and the land subsides, and relative sea level rises by the sum of the two in metres, whatever the mechanism of each. That is a statement about the world, not a modelling preference. The safety factor multiplies the sum because multiplication is the form of an engineering factor of safety, in which the design value is the nominal value scaled by a margin, and because multiplication alone makes the margin proportional to the hazard: a larger aggregate hazard earns a proportionally larger absolute cushion. An additive allowance does not have this property. A fixed freeboard of 0.6 m is the same whether the projected rise is one metre or two, so its protective share shrinks exactly as the hazard grows; the failure of a fixed freeboard to scale with the hazard is the precise deficiency this paper identifies in the city's present standard. The multiplicative form is therefore the one functional choice that delivers the proportionality the argument requires.

The alternatives are not rivals at the same layer. The methods a reviewer would name do not compete with the CRSF so much as occupy different layers of the same problem, and locating each is itself part of the justification. Expected-utility maximization is not difficult here; it is ill-posed, because it requires a probability distribution over outcomes to take its expectation, and the central finding of the preceding analysis is that the distribution is the very thing that is unknown, deep rather than statistical, with a fat and poorly constrained upper tail. Bayesian updating is a procedure for revising belief as evidence arrives, not for setting a design margin; the revision it describes is exactly what the monitored triggers and adaptive pathways of Section 8 perform, so Bayesian reasoning is present in this framework, in the monitoring layer rather than the margin. Real-options analysis values the flexibility to stage, defer, and switch investments, which is the substance of the adaptive-pathways and investment-tipping-point reasoning this paper has already adopted (de Ruig et al., 2019; Kool et al., 2026); it governs the path to the target, not the target itself. Multi-criteria decision analysis ranks discrete alternatives against weighted criteria, which is a selection problem rather than a target-setting one, and is the method Vancouver's own Phase 2 assessment used to compare options zone by zone (City of Vancouver, 2016). Each of these sits downstream of the question the CRSF answers, which is how large a margin the chosen levers must collectively be capable of reaching.

Robust decision-making is the right family, and the heuristic is its governable proxy. The methods that do address the same question, the setting of a margin under deep and possibly unquantifiable uncertainty, are robust decision-making and info-gap decision theory: the first seeks strategies that perform acceptably across the full range of plausible futures rather than optimally for any one, and the second, working explicitly without probabilities, asks how much uncertainty a decision can absorb while still clearing a critical threshold (Ben-Haim, 2006). A consequence-scaled safety factor targets the same property, robustness across the credible range, in closed form, without the scenario ensembles and computation those methods require; the preceding analysis already named robust decision-making and the precautionary principle, rather than a single computed multiplier, as the logic the situation calls for (Kopp et al., 2019). That ordering is not novel to this paper: comparing optimal, precautionary, and robust strategies against a deeply uncertain threshold hazard, Lempert and Collins (2007) found that robust approaches can capture the intent of the precautionary principle while outperforming optimization once the uncertainty is sufficiently deep. What the heuristic adds is fitness to the decision it must inform. The decision-maker here is not an analyst but a municipal council and an electorate, who under the Vancouver Charter must authorize the borrowing that builds the works (s. 242). A formal robustness or info-gap analysis is a tool for the analyst's desk; it is not what is put to voters in a borrowing by-law. A single legible and defensible figure, with its derivation visible, is. The safety factor S is, in this framing, openly a policy parameter rather than a physical constant: it encodes a societal tolerance for catastrophic and partly irreversible loss, and locating that value-laden choice with the democratic decision-maker is not a weakness of the method but a correct placement of the decision, consistent with the governance argument this paper makes throughout. The CRSF is, in short, a heuristic built to be governed: legible enough to authorize, principled enough to defend, and robust by construction where a precise optimum cannot be had.

It might be objected that multiplying projections already drawn from the upper tail double-counts conservatism. It does not. The safety factor is held at or below the 1.5 that aviation, the most safety-critical discipline, applies to its limit load, and it covers only what the hazard projections themselves do not: the wave run-up and datum allowances, the processes outside the present models, and the lead time prevention requires. None of these is represented in the choice of C, so the factor is not a re-inflation of the climate tail. The premium that engineering ethics attaches to catastrophic and irreversible loss is not a further quantity the factor must span but the reason its level is set at aviation's rather than lower: the consequence is why the margin against those unrepresented gaps is generous rather than thin, not a second representation of the tail that C already carries. Applied across the credible range of each term, the formula yields three order-of-magnitude planning targets rather than a single false-precise figure, consistent with the structural rather than exact character of this paper's quantitative claims (Table 1).

Table 1

Coastal Resilience Safety Factor: Three Planning Scenarios for Vancouver

Scenario	C (m)	R (m)	C + R (m)	S	T = (C + R) × S (m)
Conservative	0.90	0.50	1.40	1.10	1.54
Moderate	1.50	1.25	2.75	1.25	3.44
Best practice	2.00	2.00	4.00	1.50	6.00

Note. Each row is a distinct planning assumption, not a probability-weighted average. The conservative row takes the lowest credible value of each driver with a minimal safety factor; the moderate row takes mid-range drivers with an intermediate factor; the best-practice row takes upper-bound drivers with an aircraft-grade factor. Targets are shown to two decimal places to reflect the calculation, not to imply that the hazard is known to that precision; the moderate target is rounded from 3.4375. C = climate-driven sea level rise; R = Cascadia coseismic subsidence; S = safety factor; T = planning target.

The contingency of the rupture, met head-on. A reviewer may object that a Cascadia rupture is too improbable within a structure's design life to warrant carrying its subsidence in the target at all. The objection deserves a more honest answer than the recurrence of a tide can give: a king tide is deterministic and certain to return hundreds of times within that life, whereas a megathrust is a genuinely contingent event, with a 10 to 15% chance over fifty years and roughly one in four across a hundred-year design life (Wirth et al., 2025). The rupture is thus more likely than not to spare any single structure, and to call it a matter of when rather than whether would overstate the case. The design question is not whether the rupture is certain but whether the possibility of its coinciding with an already-elevated sea, within the life of what is built, is credible and consequential enough to design against; it is both.

Paleoseismic evidence from buried coastal soils records repeated great megathrust earthquakes over the past 3,500 years, with a mean recurrence interval of roughly 500 years but pronounced variability between successive events, the most recent a magnitude-9 rupture in January 1700 (Atwater & Hemphill-Haley, 1997). That record establishes the hazard as documented and recurrent without licensing any claim that it is imminent: the same irregularity that makes the rupture credible is what forbids predicting its arrival. What justifies carrying R, then, is not its timing but the asymmetry of the error, the logic that already governs the climate tail. Coseismic subsidence is instantaneous and permanent, so a structure built without the allowance is underbuilt from the moment the rupture comes, with no chance to raise it ahead of the flooding that follows and at precisely the time regional response capacity is itself destroyed. The margin is not an extra layer of conservatism beyond ordinary practice but a consequence of it: any dike protecting the region's lifelines must already be engineered to survive a great subduction earthquake, the province's own costing devoting roughly a third of its dike-upgrade estimate to seismic ground improvement (Section 7), and the subsidence is simply the permanent vertical signature of that same earthquake. To design for the shaking while sizing the crest as though the land will not drop is to accept the rupture for one purpose and deny it for another. The recommended floor, finally, carries only a mid-range value of R, not the full metre or more the upper tail allows, so the standard urged here already declines to assume the worst case on the very driver whose timing is least known.

The result reframes the city's current standard precisely. Vancouver's flood construction level, a freeboard of roughly 0.6 m over a one-metre projection, sits near 1.6 m, essentially the conservative corner of this framework: the corner that assumes the lowest climate trajectory, the smallest credible earthquake, and the slimmest safety premium at once. The moderate target is roughly twice the present standard and the best-practice target roughly four times it. The civic implication, developed in the Recommendations, is that the moderate figure is not an alarmist outlier but the lowest defensible target the framework returns, the number a prudent planner reaches by treating each pressure at its central value rather than its most hopeful one, while the best-practice figure is the appropriate aspiration for long-lived and critical assets.

Section 6: Vancouver's Policy Commitments and Planning Frameworks

Over the past decade, Vancouver has produced an extensive body of policy, planning documents, and strategic frameworks addressing sea level rise adaptation. The city has positioned itself as a leader in coastal climate adaptation in Canada, beginning with the adoption of its Climate Change Adaptation Strategy in 2012, the first such comprehensive strategy in the country. This section documents what the city has explicitly committed to do, the frameworks it has created to guide those commitments, and the gap between policy and the state of the physical infrastructure meant to protect residents and assets.

A Three-Phase Technical Assessment

Between 2014 and 2018, the City of Vancouver commissioned a three-phase Coastal Flood Risk Assessment (CFRA) to characterize coastal hazards, evaluate adaptation options, and establish a prioritized implementation timeline. The work was conducted by specialist teams including Northwest Hydraulic Consultants, Compass Resource Management, Ebbwater Consulting, and Urban Systems.

Phase 1 (2014): Hazard characterization. The first phase identified and quantified flood hazards and their consequences across Vancouver's shoreline, modelling joint-probability scenarios that combined sea level rise, storm surge, tidal effects, wind set-up, and wave action to estimate future flood extents and depths. It identified the flood construction levels (FCLs), regulatory thresholds for building placement and design, and established the baseline understanding of which assets, populations, and infrastructure were at risk (City of Vancouver, 2014a). As the city later summarized this phase, one metre of rise combined with a major storm surge (a 1-in-500-year event) would leave roughly 13 square kilometres of land and buildings, worth about CAD 7 billion on a 2013 assessment, exposed across the city (City of Vancouver, 2018b).

Phase 2 (2016): Options across eleven coastal zones. The second phase mapped eleven distinct flood hazard areas around Vancouver's coastline and developed preliminary adaptation options for each, evaluating a spectrum of strategies: protection (dikes, green infrastructure, flood walls), accommodation (raising buildings and infrastructure), and retreat (managed relocation from the highest-risk zones). Phase 2 used a structured decision-making methodology, with stakeholder workshops to clarify community values and characterize the trade-offs of each option (City of Vancouver, 2016). Its consequence modelling is notable: a major flood in the Fraser River zone alone could affect roughly 280 commercial and industrial buildings, damage more than 400 homes, and generate over CAD 300 million in losses (in 2018 dollars). The report concluded that "protecting these assets is both important and feasible" (City of Vancouver, 2016), a judgment reached, it should be noted, under assumptions about available funding rather than under the engineering principle of margin proportional to consequence.

Phase 3 (2018): Sea Level Rise Planning Framework. The third phase synthesized the earlier work into a Sea Level Rise Planning Framework (SLRPF) that prioritized and sequenced action across the eleven zones, established timelines for when interventions should begin, and provided guidance for integrating sea level rise into the city's broader planning. It was explicitly designed as an implementation tool, marking the intended transition from assessment to action (City of Vancouver, 2018a, 2018b).

The Flood Construction Level Standard

Concurrent with the assessment, in 2014 the city amended the Vancouver Building Bylaw to establish new flood construction levels for buildings in flood-prone areas, set at an elevation that accounts for one metre of sea level rise by 2100 plus 0.6 metres of freeboard. New buildings in designated flood hazard areas must place their habitable floor levels (or the underside of wood construction) at or above the FCL, across the three primary flood zones: the Fraser River Foreshore, False Creek, and the Downtown and Port Lands (City of Vancouver, 2014b). Unlike prior codes, the 2014 standard embedded climate-driven sea level rise into development regulation, a deliberate and forward-looking shift, albeit one that governs only new construction.

The Coastal Adaptation Plans

Fraser River (2017–2018). The first Coastal Adaptation Plan (CAP) focused on the Fraser River Foreshore, a sixteen-kilometre stretch encompassing residential neighbourhoods, Musqueam First Nation lands, industry, and recreation. Using participatory, values-based engagement with residents, businesses, and the Musqueam First Nation, the plan's final report identified community values, proposed flood management principles, and outlined adaptation strategies; a foundational Sea Level Rise Primer was also produced to support later phases (EcoPlan International, 2018). The process has, however, largely remained in the engagement and planning phase.

False Creek and the Sea2City Design Challenge (2019–2023). A second CAP focused on False Creek, the narrow inlet bordering downtown Vancouver. In 2021 the city launched the Sea2City Design Challenge, a twelve-month international competition in which two multidisciplinary teams developed concepts for adapting the False Creek shoreline, explicitly incorporating Musqueam, Squamish, and Tsleil-Waututh cultural advisors and youth voices and integrating flood protection, habitat creation, and traditional ecological knowledge (City of Vancouver, 2022). The challenge concluded with design concepts and the city began piloting outcomes on test sites, but without committing full-scale implementation timelines or dedicated capital.

The 2024–2025 Climate Change Adaptation Strategy

In 2024 the city updated its Climate Change Adaptation Strategy (CCAS), now in its third iteration, structured around five hazards, extreme heat, poor air quality, drought, extreme rainfall, and sea level rise, with more than sixty strategic actions (City of Vancouver, 2024). On sea level rise, the CCAS reaffirms the one-metre-by-2100 baseline (with two metres by 2200), and emphasizes adaptive management, community engagement, reconciliation with Indigenous Nations, and nature-based solutions. Critically, the strategy states plainly that "the funding needed to advance climate adaptation at the pace and scale required is beyond the City's capacity and will require long-term, sustainable funding from senior levels of government" (City of Vancouver, 2024). That single admission, that the city cannot finance its own strategy from its own revenues, frames much of what follows.

The Infrastructure Reality

Against this backdrop of frameworks and commitments, the state of existing protection infrastructure is sobering. In 2015, an assessment of 74 dikes across the Lower Mainland, including those relevant to Vancouver, found that the vast majority no longer met provincial standards, with dikes characterized as too low and substandard; by some estimates only about 5% of Lower Mainland dikes met contemporary design standards (Northwest Hydraulic Consultants, 2015). Upgrading the regional dike network to standard is estimated in the billions of dollars, and the Fraser Basin Council has estimated potential losses of CAD 20–30 billion should multiple dike systems fail (Fraser Basin Council, 2016). These standards, moreover, are typically calibrated against individual flood drivers; the same systematic review of the coastal compound-flood literature finds that such single-driver assessment understates risk and that accounting for the joint occurrence of drivers can appreciably lower a structure's effective factor of safety, so a dike meeting a single-driver standard may still be under-built against the compound extremes described above (Green et al., 2025). Provincial modelling underscores how these drivers stack on the Fraser in particular: even a moderate watershed climate-change scenario could raise the river's design flood level by roughly a metre across much of the Lower Mainland diking system, on top of the backwater effect of sea level rise, and updated CMIP5 projections place the median increase in peak Fraser discharge by 2100 at up to roughly a quarter, rising with both emissions and flood rarity (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2014; Shrestha et al., 2015).

The Planning–Infrastructure Gap

The city's policy work is substantive and sophisticated: it has mapped the hazard across eleven zones, evaluated the full spectrum of options, engaged communities and Indigenous Nations, updated building codes, and committed to adaptive management over a multi-decade horizon. Yet the same record documents a fundamental gap. New construction must meet elevated FCLs, but that does nothing for the hundreds of thousands of existing residents and the billions in existing assets built to older standards, and the dikes, pump stations, and seawalls protecting them remain substandard. Planning documents and design concepts, however innovative, cannot substitute for the physical infrastructure and sustained financial commitment needed to protect a city of nearly 700,000 people.

The principle is already the city's own. None of the calibration this paper urges is doctrine the city would dispute. Its Coastal Adaptation Plan for the Fraser River foreshore already states the consequence-scaled rule directly: areas where flooding would carry higher consequences should be protected to higher standards than those where it would not, and lifeline infrastructure that cannot be relocated should be protected to a standard as rare as one in ten thousand years, the same order the province named for dense urban cores (EcoPlan International, 2018). The same plan adopts the adaptive form defended in Section 8, prioritizing measures that can be phased as the sea rises, that remain feasible beyond two metres of rise, and whose flood construction levels are raised over time. The Northeast False Creek plan makes the principle concrete, requiring a continuous line of flood protection designed so that it can be raised a further metre as conditions demand, and setting that district's flood construction level above the city-wide standard (City of Vancouver, 2018c). The gap, once again, is not in the principle. The city has written the consequence-scaled, layered, revisable margin into its own plans. What it has not done is finance it, build it, or begin.

Section 7: Progress to Date and Capital Allocation

The disconnect between Vancouver's commitments and its budgetary follow-through is stark. Over the past decade the city has invested heavily in planning and assessment, but the capital actually deployed to build protection or relocate vulnerable populations remains modest relative to the identified risk.

Assessment funded; construction not. In 2024, city council heard that Vancouver will need to spend roughly CAD 1 billion over the next eighty-two years, on the order of CAD 12 million annually, to prepare for one metre of sea level rise by 2100, a figure the city has carried in its own reporting since at least 2018 (City of Vancouver, 2018b, 2024). Yet the city's budgets carry no dedicated capital line for building new coastal flood defences. Across the entire 2023 to 2026 capital plan, all seawall and waterfront work totals about CAD 17 million, and the two items that bear on flood protection, roughly CAD 5 million for coastal-flood-protection planning and under CAD 2 million for coastal resiliency, fund planning and design rather than construction; the remainder is maintenance and repair of the existing seawall and its marine structures (City of Vancouver, 2026). This is study and upkeep of what already exists, not the building of new protection.

Implementation status. The Sea2City challenge concluded in 2023 with design concepts; the city announced pilots on test sites (e.g., Cooper's Tidal Terrace, East Park enhancements) but has committed neither a full implementation timeline nor dedicated capital for protecting the False Creek shoreline (City of Vancouver, 2022). The Fraser River CAP's final report dates to 2018, yet years later no major dike upgrades, raised shoreline infrastructure, or large-scale accommodation or retreat projects have been funded for this highest-risk zone (EcoPlan International, 2018). The one concrete, city-wide measure remains the 2014 FCL update, which protects only new development.

The dike and shoreline gap. Beyond the substandard condition documented in 2015 (Section 6), the city's recent spending tells the story: it reports putting roughly CAD 30,000 per year into dike inspection and a further CAD 300,000, partially funded by the province, into sea-dike planning and assessment, funds to understand the problem, not to solve it (Labbé, 2026). For scale, raising a single existing seawall by 2.3 metres has been estimated at CAD 300–400 million to build plus CAD 4 million per year to maintain (City of Vancouver, 2016). Scaled across eleven flood zones, the implied cost rapidly exceeds a billion dollars, the figure the city has calculated but cannot currently finance. The city's figure, moreover, is only the city's. A provincial Class D estimate put the cost of adapting Metro Vancouver's coastal and Fraser River dikes to 2100 sea level rise at roughly CAD 9.5 billion in 2012 dollars, an order of magnitude above the city-only number and, by its own terms, exclusive of the ongoing maintenance such works require (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2012). The single largest component was not the dikes themselves but the seismic ground improvement beneath them, at roughly CAD 3.25 billion; and because the estimate is in 2012 dollars and order-of-magnitude only, construction-cost inflation alone has since driven the real figure materially higher.

The cost of the adequate standard. The provincial CAD 9.5 billion is the price of the standard the region has already judged insufficient: it buys protection against roughly one metre of rise, the conservative-corner figure the calibration of Section 5 identifies as the lowest defensible target. Two adjustments move it toward the cost of an adequate one. The first is time. Carried from 2012 dollars at construction-sector inflation, which has outpaced general consumer-price inflation over this period and is the appropriate escalation basis for civil works of this kind, the same one-metre programme would cost roughly CAD 14 to 17 billion to build today, before any change in the target. The second adjustment is the target itself, and it does not multiply the cost by 3.4. The largest component of the provincial estimate was not the dikes but the seismic ground improvement beneath them, roughly a third of the total, and that cost is fixed by the earthquake rather than the water: it does not grow as the design height rises. Land acquisition grows with the widening footprint of a taller structure, but only in rough proportion to height. It is the embankment that scales fastest, because a dike's cross-section grows faster than its crest: raising the wall raises the base beneath it, so volume, and cost, climbs more steeply than height. Roughly a third of the figure is therefore fixed against the rising target while the remainder climbs at rates from linear to steeper. Combining both adjustments, an order-of-magnitude estimate places the cost of meeting the moderate standard of 3.4 m through protection alone in the rough range of CAD 25 to 50 billion in current dollars, and the best-practice standard of 6 m higher still, plausibly approaching or exceeding CAD 80 billion. One caution must travel with these figures, and it follows from this paper's own argument: they extrapolate a dike estimate, and so they price the most capital-intensive lever carried to the full target, the very all-protection response that Sections 5 and 8 hold to be neither the least-cost nor the least-harm way to meet the standard. They are best read as an upper bound on the most expensive lever, not as the cost of the spatially varying mix of protection, accommodation, advance, and retreat the paper recommends; that mix is what the lever-by-lever, place-by-place costing called for in Section 10 would price, and it is the figure a treasury could ultimately budget against. These ranges are the structure of the cost, not its measure. Two features survive the imprecision regardless. The numbers are capital only, exclusive of the perpetual maintenance protection demands in every year of its existence, which retreat does not (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2012). And whatever the exact total, and whichever mix of levers delivers it, it is large enough that no plausible refinement returns it to a sum the city could finance from its own revenues, which is the conclusion the city has already reached in its own words.

Absent from the budget outlook. A further indication of where adaptation sits in the city's priorities lies in what its own budget planning does not say. The 2026 to 2030 Budget Outlook, the document that frames the financial horizon against which near-term decisions are weighed, itemizes the cost pressures the city expects to manage over five years: Metro Vancouver utility levies, salary and benefit escalation, external agency charges, fixed-cost inflation, and the renewal of critical infrastructure funded by a standing one per cent property-tax increment. Each is named, quantified, and tracked. Sea level rise is not among them. The outlook carries no coastal-adaptation line, no projection of the roughly one billion dollars the city's own reporting has attached to one metre of rise since 2018 (City of Vancouver, 2018b, 2024), and no reference to the coseismic subsidence that Section 5 shows could compound the hazard; the nearest adjacent language is a general acknowledgement of historical under-investment in infrastructure renewal (City of Vancouver, 2025). The omission is consequential. A cost that does not appear in the budget horizon does not shape the tax trajectory, does not compete for capital against the levies and settlements that do, and is not weighed as a discrete obligation. Adaptation, on this evidence, has been calculated but not differentiated: it remains folded into general renewal rather than standing as the distinct and escalating commitment the engineering estimates describe. A pressure the forward ledger does not name is unlikely to be funded at the scale those estimates require.

The acceleration problem. Crucially, this timeline has not kept pace with the science. The phased planning assumed mid-range acceleration and horizons of fifty to seventy years before major protective action would be required. But the observed rate has accelerated (Hamlington et al., 2024; NASA, 2025), and recent synthesis suggests it could reach roughly one centimetre per year by 2100 (Stokes et al., 2025). If so, the window for orderly adaptation compresses: defences once thought adequate to 2050 may fall short by 2035–2040. An adaptive-management framework is sound only if the hazard does not outrun the learning cycle.

The standard mismatch. This returns to the calibration analysis of Section 5. The city's FCLs embody a margin of roughly 1.5 times the projected hazard, a routine factor, even though the city's own Phase 2 consequence modelling (Section 6) describes a catastrophic consequence: a major urban centre, hundreds of thousands of people, tens of billions in assets. The mismatch is not hidden; it is embedded in the city's own documents, where feasibility was judged against assumed budgets rather than against the principle of margin proportional to consequence. This default is not merely inferred from budgets; it is visible in the city's own practitioner community. In interviews with 27 Vancouver flood-management and coastal-adaptation professionals, protection through dikes and seawalls was the favoured approach precisely because it was seen as the least expensive and least disruptive option, while managed retreat was regarded as expensive and unfamiliar (Doberstein et al., 2020). The provincial record states the same gap in starker terms. The benchmark the province uses for Fraser dikes, the 1894 flood of roughly 17,000 cubic metres per second, has been placed by recent frequency analysis at about a 1-in-500-year event, and the formal minimum standard is the higher of that or a 1-in-200-year flood, which most existing dikes do not meet (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2014; Shrestha et al., 2015). Having modelled Fraser flood profiles against sea level rise of up to two metres and against climate-driven increases in peak flow, the province observed in the same analysis that much higher standards, on the order of the 1-in-10,000-year level the Netherlands applies to its major coastal cities, may be justified for densely populated urban areas (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2014). It named the consequence-scaled standard and built to the routine one: a roughly 1-in-500-year fluvial benchmark set against an urban marine benchmark twenty times rarer is the calibration gap of this paper restated in the province's own figures. The city's coastal standard rests on the same footing: the flood construction level it raised in 2014 is built on one metre of rise combined with a 1-in-500-year storm surge, so the 1-in-500 benchmark holds across both the riverine and the marine hazard (City of Vancouver, 2018b).

This is the second, and arguably more troubling, gap: not between what the science shows and what the city acknowledges, but between what the city commits to do and what it actually funds.

The Double Escalation Problem: Construction Inflation and Post-Disaster Recovery Costs

Deferring coastal protection introduces two compounding cost escalations, either of which alone would justify urgency.

Construction cost escalation. Construction costs do not stand still, and in recent years have risen faster than general consumer prices. Statistics Canada's building construction price indexes posted their steepest increases on record in 2022, when residential building costs across the eleven-city composite rose 19.1% in a single year and non-residential costs rose 12.5%, the largest annual increases since those indexes began (Statistics Canada, 2023). The surge has since eased, but costs have kept climbing, roughly 3 to 4% year over year into 2025, with structural steel and other metal products pushed higher by tariffs (Statistics Canada, 2025). The implication for deferral is direct: a CAD 1 billion project today does not stay CAD 1 billion. At a conservative 5% annual escalation it approaches CAD 1.6 billion in ten years and roughly CAD 2.6 billion in twenty. Front-loading protection while costs are near current levels is materially cheaper than building the same works in the 2050s or 2060s.

Post-disaster recovery costs. More consequential is the cost of recovery versus prevention. The evidence is consistent: the World Bank's Lifelines study finds that resilient-infrastructure investment in low- and middle-income countries returns on the order of four dollars per dollar (Hallegatte et al., 2019), and the U.S. National Institute of Building Sciences finds about six dollars saved per dollar of federal mitigation, rising to about seven-to-one for riverine-flood measures such as acquiring or elevating flood-prone buildings (National Institute of Building Sciences, 2018). A major flood that strikes before protection is complete would therefore impose losses several-fold larger than prevention would have cost.

Hurricane Katrina is the sobering precedent. NOAA records Katrina as the costliest hurricane in U.S. history, with roughly USD 125 billion in damage in 2005 dollars (National Oceanic and Atmospheric Administration [NOAA], 2023); adjusted for inflation, that is about USD 201 billion in 2024 dollars (National Centers for Environmental Information [NCEI], 2025). Recovery from such an event is, moreover, partial by nature. Writing a year after the storm, Kates et al. (2006) projected that the city's heavy losses in population, housing, and employment would likely persist and at best only partly recover, since disasters tend to accelerate a community's existing trajectory and New Orleans had been losing population for decades; several of its major public-housing developments were already slated never to be rebuilt. Two decades on, that projection has substantially held: the city counted roughly 362,000 residents in 2025, about three-quarters of its 2000 census population of roughly 485,000, the benchmark The Data Center treats as the reliable pre-Katrina measure (The Data Center, 2026). The defining contrast between prevention and recovery is not only cost but reversibility: a dike built in time protects assets going forward, whereas a flood destroys assets that cannot be fully recovered and displaces populations that may not return.

Why deferral compounds. The two escalations multiply. Each year of delay raises the nominal cost of the protective works (construction inflation) and raises the probability that a flood occurs before protection is complete, triggering recovery costs several times larger than prevention; a government that cannot finance prevention now will be even less able to finance recovery later. To defer is, in effect, to accept the probability of catastrophic and partly unrecoverable loss.

The Political Economy of Deferred Action: Funding Collapse Under Cascading Crises

Vancouver's reliance on senior-government funding exposes a deeper vulnerability: the fiscal and political capacity of the province and the federal government to fund adaptation erodes as the number of claimant jurisdictions grows, and collapses if major flood events strike before adaptation is complete. Vancouver's own adaptation professionals anticipate precisely this drift toward post-disaster reaction: in interviews, retreat was expected to arrive as a top-down measure applied in the aftermath of a disaster and underwritten by provincial and federal funding, and lack of funding, not lack of engineering, was already identified as a strong barrier to acting earlier (Doberstein et al., 2020).

That the problem exceeds the city's own fiscal capacity is reasonable enough: coastal adaptation is of provincial and national scale, and the political economy of who funds it is itself part of the adaptation problem rather than a separate matter (Kopp et al., 2019). But the city's reliance on senior governments assumes they have both the capacity and the will to fund many jurisdictions at once, and that this capacity will still be available if the city delays its request. That assumption is fragile.

British Columbia faces sea level rise across dozens of coastal municipalities, regional districts, port facilities, fishing communities, First Nations territories, industrial areas, and low-lying agricultural lands: the entire coastline, not Metro Vancouver alone. The federal responsibility spans both seaboards and the Arctic: Halifax, Saint John, and St. John's on the Atlantic; communities beyond Metro Vancouver on the Pacific; and Arctic infrastructure critical to sovereignty and to Indigenous communities. The competition for adaptation funding is multilateral, and the aggregate need dwarfs available resources.

Under these conditions, the early submission of a well-developed, evidence-based plan, which Vancouver has, confers advantage: a jurisdiction that can show concrete risk assessment and a prioritized timeline is better positioned to secure scarce funds than one arriving after a disaster. Deferral erodes that position each year, as other claimants advance and senior budgets face competing pressures.

The more severe risk is deferral past the point of a major flood. Katrina, the precedent set out above, was a single-event disaster striking a single city, with no other comparable emergency competing for federal resources, and even then recovery was slow, incomplete, and widely judged inadequate. Now consider sea level rise accelerated to a centimetre a year, with a single storm system driving compound flooding across multiple regions at once: False Creek and the Fraser foreshore, Puget Sound, San Francisco Bay, Atlantic cities, thousands of kilometres of coast, millions displaced, tens of billions in assets lost. In that world, recovery funding must be split across simultaneous crises and many jurisdictions; the amount available to any one shrinks as claimants multiply. That pool of claimants is, moreover, both vast and disproportionately poor: the populations most exposed to coastal flooding are concentrated in resource-constrained countries of coastal Asia (Kulp & Strauss, 2019), which only widens the gap between aggregate need and available capacity. A single city seeking one billion for prevention before a disaster is a feasible political conversation; multiple regions each seeking ten billion for recovery after disasters is a fiscal impossibility.

The logic is unforgiving: the longer Vancouver delays seeking adaptation funding, the lower the probability that adequate funding will be available when needed; and if action is deferred until a major flood occurs, the probability of meaningful senior-government recovery assistance approaches zero. This is not a matter of will but of arithmetic: there are not sufficient resources in the provincial or federal treasury to prevent catastrophic losses across many regions at once. The only viable strategy is to fund adaptation before disasters occur, while fiscal capacity exists and while the claims upon it remain manageable.

Section 8: From Diagnosis to Response: Adaptation Under Deep Uncertainty

The preceding sections establish a diagnosis: a measure of sea level rise is now committed regardless of emissions trajectory, the upper tail of the distribution is heavy and not reducible by any plausible mitigation, and Vancouver’s protective infrastructure is scaled to a hazard smaller than the one physics describes. The honest response to that diagnosis is not despair but a change of question. The relevant question is no longer only how high the wall must be, but what the least-harm allocation of finite resources is across a hazard that cannot be precisely bounded. That reframing is not a retreat from rigour; it is what rigour requires once the uncertainty is acknowledged to be deep rather than merely large. This reframing also guards against a subtler failure. Structural, engineered responses are often the more politically palatable precisely because they demand less direct acknowledgement of the threat, and an adaptation discourse anchored in them can harden into a techno-optimism that trusts engineering to dissolve a risk which may instead require social change (Siders et al., 2021). An engineering-margin argument that stopped at the height of the wall would be vulnerable to exactly that charge; pricing all four levers is how it escapes it. Where the probability distribution itself is uncertain, the rational course is not to optimize against a single best estimate but to choose strategies that perform tolerably across the range of futures the science leaves open, and that preserve the ability to adjust as the future resolves (Naughten et al., 2023). The sections that follow turn from what Vancouver faces to what a defensible response would look like. They offer not a project list but the logic such a list would have to satisfy.

The levers are coupled. Section 5 introduced the menu of responses, protection, accommodation, advance, and retreat, and argued that an honest safety-factor analysis must price all four rather than defaulting to an ever-higher wall. The first thing to say about that menu is that its items are not independent: choosing one lever now changes the cost and feasibility of the others later. The clearest instance is the dynamic coastal scholars call the levee effect. Once a barrier is built, development intensifies behind it, drawn by the apparent security, and that accumulated development becomes the political and economic reason the barrier can never be abandoned (Hino et al., 2017). Protection manufactures its own permanence. Each increment of fortification raises the value of what sits behind it and so forecloses the retreat that might later prove cheaper or safer; defences built incrementally, without foresight, quietly remove future choices from the table. The same coupling appears at the scale of the household. Survey work across four coastal countries finds that in-situ adaptation, the elevating and flood-proofing of individual homes, measurably defers the decision to leave, but that its protective value has limits under the highest flood frequencies (Duijndam et al., 2025). Defence postpones retreat; it does not abolish the eventual need for it. A strategy that treats the levers as a one-time choice rather than a sequence will tend to over-invest in the lever that feels safest now, and discover too late that it has spent its way out of the alternatives. And the binding constraint is temporal as much as fiscal: because the transformative responses carry long lead times, a quantified pathway analysis of a failing gravity-based coastal drainage system finds that adapting the existing system first can consume the very years a later switch to pressurization or retreat would require, foreclosing the transformative path before its threshold even arrives (Kool et al., 2026).

The cheapest option is not the least-harm option. If the levers must be sequenced, the question is how, and here a recent costing of managed retreat is instructive precisely because it makes the trade-offs quantitative. Studying an eroding shoreline in Hawaii, Setter and colleagues compared three ways of executing a retreat: all-at-once, in which exposed properties are acquired and removed proactively; threshold-based, in which each property retreats when the shoreline crosses a predetermined trigger; and reactive, in which nothing moves until a structure fails (Setter et al., 2023). The finding is the one an engineering-ethics argument should expect. The reactive approach carries the lowest direct cost and the highest harm, loading public-safety and environmental damage onto the moment of failure, when collapsed structures and their contaminants enter the nearshore. The proactive approaches cost more in dollars booked early but are the least-harm over the life of the adaptation. The cheapest line item, in short, is not the least-harm course, which is the same conclusion Section 5 reached about the wall, now reached from the side of retreat. The comparison also makes explicit what the discount rate usually buries: because retreat, once done, carries almost no recurring cost while protection must be maintained in perpetuity, the ranking of the levers depends on the time horizon and discount rate chosen, and over the horizons sea level rise actually operates on, the lever that looks politically hardest is often the economically rational one (Revell et al., 2021); a recent British Columbia review frames the same asymmetry, noting that retreat's costs fall once while dikes and seawalls demand costly reconstruction at the end of their lifespan, and that conventional discount rates penalize exactly this kind of high-upfront, long-horizon investment (Cross et al., 2024). The same accounting explains why no single lever is right everywhere. A comparative study of six coastal cases finds that hard protection is economically beneficial for dense, high-value urban cores even against high-end rise, but that for low-density rural and agricultural land its benefit-cost ratio typically falls below one, and can turn negative once the squeezed coastal wetland is counted as a loss (Hinkel et al., 2018); the advance lever, the reclamation or raising of land, appears mainly where land values are high enough for the new real estate to finance the works, which makes it less a general solution than a narrow financing manoeuvre. For a city built across both a dense core and a low-lying agricultural margin, the defensible answer is therefore likely to be a different lever in each. The figures from a Hawaiian beach do not transfer to a leveed delta and should not be read as Vancouver numbers; what transfers is the structure of the trade-off, and the discipline of pricing harm rather than only outlay.

A trigger is more honest than a deadline. That same study supplies the mechanism by which a sequence can be made governable rather than improvised. The threshold-based approach, in which retreat is triggered when an agreed physical marker is reached, is the operational form of the principle the deep-uncertainty literature calls keeping options open. It commits not to a date but to a condition, and so adjusts automatically as the hazard resolves faster or slower than projected; it is, in effect, the rolling easement that the managed-retreat literature has long proposed, rendered as policy (Hino et al., 2017). And the trigger is close to costless to choose: in the same Hawaiian comparison, threshold-based retreat cost about the same as the cheapest reactive option, a maximum difference of roughly 1.5-fold, yet it spared nearly all of the public-safety and environmental harm that reactive retreat incurs and returned the most recovered beach area per dollar spent (Setter et al., 2023). The trigger is therefore not only the more honest commitment but very nearly the least-cost one consistent with avoiding harm. This is the logic that the planning literature has formalized as dynamic adaptive policy pathways, which specify not one committed future but a sequence of responses, each with a monitored trigger and a known lead time, and switch between them as conditions cross agreed thresholds (Kool et al., 2026). A quantified application to a failing coastal drainage system shows both the promise and the discipline of the method: because the timing of every threshold depends heavily on which emission future arrives, monitoring becomes the central adaptive act, and because each transformative response needs years of lead time, the decision to switch must be taken before the threshold is reached rather than when it is breached. Independent economic modelling reaches the same conclusion from the cost side. Coupling a scenario-based cost-benefit analysis with adaptation pathways for Los Angeles County, de Ruig et al. (2019) found that a pathway which invests early in a lighter protective strategy and transitions later to a higher standard can be more economically efficient, by up to roughly 10% in net-present-value terms, than committing to a single fixed strategy at the outset. The same study identifies the hazard in waiting too long: past an "investment tipping point," a delayed transition can never recover the efficiency that an earlier switch would have captured, because capital sunk into the initial strategy is stranded the moment the higher standard supersedes it. That is the economic counterpart to Kool's lead-time argument: the trigger must be pulled before the threshold is breached, not after. For a jurisdiction that cannot know whether it faces one metre or two, a trigger-based commitment is more defensible than either a fixed protective standard that may prove inadequate or a premature abandonment that may prove unnecessary. It converts an unbearable single decision into a sequence of bearable ones, and it sets the terms in advance, when deliberation is calm, rather than in the aftermath of a flood, when it is not.

The earthquake will not wait for a trigger. The case for staging rests on lead time: a trigger works only because the hazard it watches, the slow climb of the sea, announces itself far enough ahead that the next increment can be designed, funded, and built before it is needed. One component of the margin defeats that condition entirely. Coseismic subsidence does not climb; it arrives in minutes, with no precursor a monitoring programme could read and no interval between signal and event in which to act. The part of the target that comes from R is therefore precisely the part adaptive pathways cannot accommodate, because there is no increment to add as the hazard materializes when the hazard materializes all at once. This does not set the two frameworks against each other; it marks the boundary the adaptive logic draws by its own criterion. Staging is licensed where monitoring buys lead time and forbidden where it cannot, so the same reasoning that defers the climate margin requires committing the subsidence margin in advance. The target thus separates into two layers with different obligations: a climate share approached on a schedule of monitored triggers, and a subsidence share that must stand in the committed base from the outset, because the structure either carries it when the ground drops or it does not. The honesty this demands cuts the other way as well. Committing that base means paying for a margin that will probably not be called upon within any single structure's design life, a real cost and not a rhetorical one. Three things bound it: the premium is modest against works already underway, since the seismic ground improvement the same rupture necessitates is built regardless (Section 7); the committed base carries only a mid-range value of R, not the upper tail; and the alternative to the premium is the one outcome adaptation exists to prevent, a defence overtopped at the moment the region can least respond, with no second chance to raise it. Against a loss that is sudden, permanent, and uninsurable by deferral, the anticipatory margin is not a departure from the adaptive discipline but its most exacting application.

The arithmetic of delay. If the adequate standard costs on the order of tens of billions (Section 7), the timing of that expenditure is not a detail but a determinant of its size. Delay is not neutral deferral; it is cost-multiplying, through three compounding mechanisms. The first is price: construction-sector inflation means the same physical works cost materially more in each year they are postponed, so a programme deferred is a programme enlarged. The second is damage: the expected annual loss from coastal flooding rises as the protection gap persists, climbing, in independent modelling of the city's exposure, from roughly CAD 30 million a year now toward several hundred million a year by late century, so years of delay are paid in flood losses adequate protection would have averted (Ness et al., 2021). The third is foreclosure: each year of unmanaged development behind the present line of defence raises the value any future protection must defend and deepens the levee effect, retiring the cheaper accommodation and retreat options before they can be chosen (Hino et al., 2017). Against these stands the asymmetry that governs the whole problem: prevention undertaken early is cheaper than prevention deferred and far cheaper than recovery, in the ratios Section 7 documents. To wait is not to conserve the expenditure but to inflate it, while transferring the difference from a budget line the region controls to a disaster bill it does not.

Insurance is the ordinary name for this logic. The reasoning here is not exotic; it is the logic of insurance, which societies apply without hesitation to risks far smaller than this one.

Households insure against house fires, car accidents, and cancelled trips, events whose annual probability is low and whose consequences, however serious to the individual, are bounded. Sea level rise inverts both terms: its arrival is not improbable but effectively certain, and its consequences are not bounded but compounding and partly irreversible. A premium paid against a remote and limited loss is treated as prudence; a premium paid against a certain and unlimited one ought to be treated as more prudent still, not less. That the second premium is the harder one to authorize, despite resting on the stronger actuarial case, locates the obstacle in politics rather than analysis: the failure to fund adaptation is not a failure to understand the risk but a reluctance to pay, within the present term, for a loss that falls due beyond it. This temporal structure, in which the costs of acting fall within a political term while the costs of not acting fall beyond it, is what makes adaptation finance an instance of what Garnaut (2008) called a "diabolical policy problem": a challenge whose deep uncertainty and long time horizons make it resistant to ordinary political decision-making. The safety-factor margin argued for above is, in these terms, simply the premium, and the only question an insurer would ask of it is whether it is large enough.

When to begin. The trigger logic established earlier governs how far to escalate the margin and which lever to reach for next; it does not license waiting to begin. Applied to the foundational decision, whether to start building at all, the same lead-time reasoning shows that the threshold has already passed. A coastal-protection programme of this magnitude is not an act but a schedule. The provincial costing assumed construction phased across several decades rather than years, and the city's own record bears this out: a vulnerability assessment in 2012, a flood construction level adopted in 2014, preliminary options through 2016, and an engagement and design programme that, by 2026, has returned to a fresh round of public consultation without a single major new coastal-protection structure yet built (City of Vancouver, 2014b, 2018b). The planning is mature; the construction has not begun. The lead times are long: engineering, partnership with the Musqueam, Squamish, and Tsleil-Waututh Nations, land acquisition, and phased building place something on the order of five to ten years between a decision and the first major works in the ground, and decades between those works and a completed regional system. Set that build-out against a hazard that is not waiting. Sea level rise is accelerating now (Stokes et al., 2025; Hamlington et al., 2024), the one-metre-by-2100 baseline is increasingly likely to be reached sooner, and the Cascadia rupture carries a 10 to 15 per cent probability in any fifty-year window (Wirth et al., 2025). A system that must take decades to build, set against a hazard that compounds every year and a horizon fixed at 2100, cannot be begun at leisure. The conclusion is specific: major capital construction on the first and most exposed reaches must begin within roughly the next five years, by the end of this decade, with the funding that underwrites it committed earlier still, and a first tranche of protection operational by the mid-2030s rather than merely designed. To defer that start to the late 2030s would compress the remaining build-out into the very decades in which the acceleration bites hardest and the Cascadia probability accumulates: it would plan the system to arrive just after the window in which it was needed.

The decision falls to one electoral cycle. This timetable maps onto Vancouver's governance calendar with uncomfortable precision. British Columbia holds general local elections every four years, on the third Saturday in October; the next falls on 17 October 2026, and the one after it in October 2030. A programme of this scale, moreover, is not something a council can fund from operating revenue. Under the Vancouver Charter, the city may not contract debt that is not provided for in the current year's estimates unless a borrowing by-law is passed with the assent of the electors; the Charter exempts borrowing for waterworks, sewerage and drainage, and energy-utility systems, but not the dikes, barriers, land acquisition, and seismic works that coastal flood protection requires (Vancouver Charter, 1953, s. 242). Large-scale adaptation borrowing would therefore have to be put to the voters, as the city's capital-plan borrowing already is. That places the decisive work inside a single term. The council elected in October 2026 is the one that must commission the spatially explicit costing this paper calls for, negotiate the cost-sharing commitments from the provincial and federal governments that a programme of this size demands, and assemble a phased proposal concrete enough to put to a vote. The natural moment to seek that authorization is the October 2030 election, when a borrowing question can be placed on the ballot against firm senior-government commitments and a real construction plan rather than an estimate. The lead times align: roughly one electoral cycle to plan, cost, and secure the mandate, and the cycles after it to build. The corollary is the binding one. If the council elected in 2026 treats adaptation as a problem for its successors, the costing and intergovernmental negotiation cannot mature enough to put a credible question to voters in 2030, the authorization slips to 2034 at the earliest, and construction cannot begin in earnest until the very years in which the acceleration and the accumulating seismic probability make delay most dangerous. The democratic checkpoint is not an obstacle to the timeline; it is the timeline. Beginning, in the specific sense this paper intends, is the task of the council Vancouver elects in 2026. While this paper focuses on Vancouver's response, the effectiveness of coastal adaptation in the Lower Mainland will depend critically on coordinated action across the Metro Vancouver municipalities and, equally, on alignment with the territorial governance and stewardship priorities of the Nations whose lands and waters the hazard affects.

Who decides, and who is stranded. None of this is a purely technical optimization, and it would be a failure of the argument to present it as one. The same survey that documented the limits of in-situ defence found something more troubling: the capacity to move is sharply stratified by wealth. Migration intentions rise with income, because moving is expensive, and under intensifying risk the households least able to afford relocation face the prospect of becoming what the literature calls trapped populations, immobilized in places growing less safe (Duijndam et al., 2025). The implication for a retreat strategy is direct. Left to autonomous, market-driven relocation, retreat sorts people by their means: those who can afford to leave do, and those who cannot are concentrated in the rising risk. A retreat that is not deliberately funded and governed is therefore not neutral with respect to justice; it distributes harm toward the least-resourced. This is why the governance of retreat matters as much as its economics. The managed-retreat literature frames the decision along two axes, who initiates the move and who benefits from it, and finds that the cases where residents want to relocate but no authority will help them are precisely the ones that fail, stranding communities that are disproportionately poor and, in the documented record, disproportionately Indigenous (Hino et al., 2017). A systematic review of the managed-retreat field bears this out at scale: across 135 studies the literature leans heavily on property rights, buyouts, and other market mechanisms, a reactive, market-led default the review reads as a symptom of too little attention to political economy, and one whose distributional costs fall hardest on low-income and racialized communities and on Indigenous peoples disconnected from their land in the process (O’Donnell, 2022). The danger in the city’s own admission that adaptation exceeds its fiscal capacity is that an unfunded mandate becomes, by default, the abandonment-by-inaction these cases describe. That danger is structural, not incidental. A synthesis of coastal-adaptation experience across six countries concludes that the constraint that actually binds is rarely the engineering and usually the financing, because the benefits of protection are stochastic, long-deferred, and spread across many beneficiaries, and so resist being turned into the revenue stream that would fund the works up front (Hinkel et al., 2018). That same synthesis forecasts a bifurcation: wealthier urban areas fortifying behind ever-higher defences, and poorer, more rural areas, where the economics are less favourable, struggling and eventually retreating amid conflict over compensation and liability; it calls expressly for distributional justice and transfer payments to the communities the market would otherwise strand. That is the trapped-populations finding restated from the side of policy, and it is where adaptation stops being an engineering question and becomes a question of justice. The deeper lesson is that fair procedure does not by itself secure a fair result: in a closely studied retreat in Iloilo, the Philippines, pre-existing inequalities in wealth and power produced unequal outcomes despite robust planning and broad participation, some households emerging better housed and more secure and others not (Siders et al., 2021). Justice in retreat is therefore distributive, procedural, recognition-based, and restorative at once, and must actively redress the inequities that shape who can benefit rather than presume that consultation will yield equity. A defensible adaptation is one in which the question of who bears the cost is answered deliberately and in advance, rather than settled silently by who can afford to act. That question cannot be answered for the territory of this region without the peoples whose relationship to it long predates the city, and it is to them that the paper now turns.

Section 9: Indigenous Nations and Sea Level Rise: Sovereignty, Cultural Continuity, and Essential Voices in Adaptation

The impacts of sea level rise on Vancouver extend beyond property values, infrastructure costs, and municipal budgets. For the Musqueam, Squamish, and Tsleil-Waututh Nations, whose unceded territories encompass the lands and waters of the Lower Mainland, sea level rise presents threats to territorial sovereignty, cultural heritage, and food security that differ fundamentally in kind from the risks faced by the settler city built atop their lands.

These three Nations have occupied and stewarded the Coast Salish territories for thousands of years. Their relationship to the water, the foreshore, and the river systems is not primarily economic or recreational; it is constitutive of identity, governance, and continuity as peoples. The False Creek and Fraser River areas, the very zones most vulnerable to sea level rise in the city's planning, are not merely flood-prone municipal zones. They hold historic village and settlement sites, burial grounds, gathering places, and access points to the fisheries and marine resources that have sustained these Nations since time immemorial.

Sea level rise threatens these territories in ways conventional adaptation planning does not address. Rising water will inundate archaeological sites and burial grounds, irreplaceable repositories of ancestral knowledge and remains that cannot be "relocated" or "mitigated" as a building can. Salinization and ecological change will disrupt salmon runs and other food sources central to Indigenous food sovereignty and cultural practice. And access to traditional territory for harvesting, ceremony, and cultural transmission may be constrained or severed if shorelines are armoured with concrete rather than allowed to evolve. Moreover, the standard adaptation strategies, protect, accommodate, retreat, were framed within settler assumptions about land use and property, and do not necessarily align with Indigenous governance, stewardship, or vision; in some cases, "protecting" the city could come at the expense of Indigenous access or accelerate ecological changes that undermine Indigenous food systems. The economic tools used to choose among those strategies carry the same limitation: the utility-maximization and substitutability assumptions at the heart of cost-benefit analysis sit uneasily with Indigenous conceptions of communal well-being, and many Indigenous values cannot be traded off against monetary compensation in the way such analysis requires, a point a recent British Columbia review of retreat economics makes directly (Cross et al., 2024).

The City of Vancouver has engaged the three Nations in the False Creek and Fraser River processes, and the Sea2City Design Challenge explicitly incorporated Indigenous cultural advisors and sought to decolonize coastal adaptation by centring Indigenous knowledge and values (City of Vancouver, 2022); the 2024–2025 CCAS likewise frames reconciliation as integral to adaptation planning (City of Vancouver, 2024). These are important steps. But consultation is not the same as decision-making authority. Indigenous Nations must be recognized not as stakeholders in a municipal process but as sovereign peoples with inherent rights to their territories, and as decision-making, not merely advisory, voices in any strategy affecting their lands and waters. Going forward, adaptation planning should centre Indigenous territorial rights and sovereignty; protect archaeological and burial sites under the authority of the affected Nations; prioritize Indigenous access to traditional food sources and cultural sites and the ecological health that sustains them; and treat adaptation timelines and strategies as matters determined in partnership with Indigenous peoples rather than imposed upon them. The recognition this implies is grounded in provincial law. Through its Declaration on the Rights of Indigenous Peoples Act, British Columbia has affirmed the United Nations Declaration on the Rights of Indigenous Peoples as its framework for reconciliation, committed to bring the province's laws into alignment with that Declaration, and provided for joint and consent-based decision-making agreements with Indigenous governing bodies (Declaration on the Rights of Indigenous Peoples Act, 2019, ss. 3, 6–7). The Declaration sets a standard of free, prior, and informed consent for measures and projects affecting Indigenous lands, territories, and resources, a standard distinct from and more demanding than consultation (United Nations, 2007, arts. 19, 32). Because an adaptation programme of the scale set out here cannot be financed or carried out without the province, it engages those commitments directly: the Nations' authority over decisions affecting their lands and waters is not a courtesy the city may extend or withhold but an obligation the province has already entered into in law. This is not only an ethical and legal requirement but a practical one: strategies that ignore Indigenous knowledge, rights, and long-term stewardship are likely to be less effective, less just, and less durable over the multi-generational timescales genuine adaptation demands.

Section 10: Discussion and Conclusion

This paper began from an observation and an analogy. The observation is that sea level rise is accelerating, that a measurable portion of it is now committed regardless of any emissions path still available, and that the dangerous part of its uncertainty lies in a heavy upper tail no plausible mitigation can pare away (Stokes et al., 2025; Naughten et al., 2023). The analogy is to the way every other safety-critical discipline treats uncertainty of this kind: not by building to the expected value, but by scaling the margin to the consequence of failure and to the depth of what is unknown, and, in the most demanding cases, by distributing that margin across a layered, monitored, revisable system rather than banking it in a single number. Read together, the two yield the paper's central claim, that the margin Vancouver currently carries against coastal flooding is a routine, bridge-grade factor applied to an aircraft-grade consequence, under uncertainty deeper than any for which such a factor was designed.

The argument's pivot is that this gap is not, at root, a gap in knowledge. The city has mapped its hazard across eleven zones, embedded sea level rise in its building code, engaged communities and Indigenous Nations, and committed in writing to adaptive management; its own consequence modelling describes losses in the tens of billions and displacement in the hundreds of thousands. The shortfall lies elsewhere: in the calibration of the margin, set near routine practice rather than near the consequence; in the financing, which the city concedes exceeds its own capacity; and in the political economy of deferral, where the cost of protection escalates with every year of delay while the probability of an unfunded catastrophe rises in step. Vancouver is further distinguished by a hazard absent from the jurisdictions it is usually compared with, the Cascadia Subduction Zone, whose next great rupture could add one to two metres of instantaneous relative sea level rise to whatever climate-driven rise has accumulated, so that the margin a defensible policy must carry is set by the joint distribution of two hazards rather than one (Dura et al., 2025).

From that diagnosis the paper turns to response, and the turn is itself a conclusion: once the uncertainty is acknowledged to be deep rather than merely large, the governing question is no longer how high to build but how to allocate finite resources for least harm across a hazard that cannot be precisely bounded. The four levers of protection, accommodation, advance, and retreat are coupled, so that an unconsidered choice now forecloses cheaper or safer options later, both in money and in the lead time transformative responses require (Hino et al., 2017; Kool et al., 2026). The cheapest course is rarely the least-harm one, and no single lever is right across a city that spans a dense urban core and a low-lying agricultural margin (Hinkel et al., 2018). A sequence governed by monitored triggers is more honest, and more defensible, than one governed by a fixed date or a fixed wall. And because retreat left to the market sorts people by their means, the question of who bears the cost cannot be settled silently; it must be decided deliberately, and it cannot be answered for this territory without the Musqueam, Squamish, and Tsleil-Waututh Nations as decision-making rather than advisory voices (Duijndam et al., 2025).

The conclusion that follows is narrow and, this paper has argued, difficult to escape. The planning gap is real, but it is a gap of calibration, financing, and governance rather than of science; and the only strategy consistent with both the physics and the fiscal arithmetic is to act ahead of disaster, while options and capacity remain. Front-loaded prevention is cheaper than deferred prevention and far cheaper than recovery, and recovery funding cannot be relied upon at the scale a compound, multi-region event would demand, because the pool of claimants on senior budgets is both vast and disproportionately poor. To wait is not to save money but to convert a manageable present cost into an unmanageable, partly unrecoverable future one. That is the conclusion the engineering disciplines reached long ago about margins, arrived at here from the side of public finance.

Recommendations

The argument of this paper converges on a single civic instruction: Vancouver should set its coastal design standard by the consequence it is protecting against and the hazards that bear on it, not by the central projection alone. The Coastal Resilience Safety Factor formalizes that instruction. It takes the climate-driven rise the city already plans for, adds the relative rise a Cascadia rupture could impose, and multiplies the sum by a factor proportionate to the consequence of failure. Carried through at central values it returns a target near 3.4 m; carried through at its credible upper bounds, near 6 m. The present flood construction level, roughly 1.6 m, sits not in the middle of that range but at its conservative corner, the point that assumes the lowest climate trajectory, the smallest credible earthquake, and the slimmest premium at once. The recommendations that follow translate that reframing into a standard the city can adopt, finance, and begin.

Adopt the moderate target as the binding minimum. A design flood level near 3.4 m, the figure the framework returns when each driver is taken at its central rather than its most hopeful value, should become the minimum to which new coastal works, dikes, and flood construction levels are built. This is roughly twice the present standard. It is not an alarmist outlier but the lowest defensible target the framework returns: the number a prudent planner reaches by declining to assume the best case on every variable at once.

Reserve the best-practice target for critical and long-lived assets. A target near 6 m, the upper-bound form of the same calculation, should govern works whose failure is catastrophic or whose service life runs a century or more: hospitals and emergency facilities, major crossings, trunk utilities, and anything that cannot readily be raised later. The city already accepts this logic in principle, holding lifeline infrastructure that cannot be relocated to a standard as rare as one in ten thousand years (EcoPlan International, 2018); the recommendation is to apply it consistently and to the level the compound hazard warrants.

Implement the standard as a layered, monitored, revisable margin, not a single wall. The targets above are design objectives, not an instruction to build a barrier of that height tomorrow. As Section 8 argued, the defensible way to carry a large margin under deep uncertainty is to distribute it across a sequence of protection, accommodation, advance, and retreat measures governed by monitored triggers, so that each increment is added as the hazard materializes and no early choice forecloses a cheaper or safer one later. The Safety Factor sets the margin the system must ultimately be capable of reaching; adaptive pathways set the order and timing in which it is approached, save for the subsidence allowance, which must stand in the committed base from the start because it cannot be approached by increments.

Assign the annual review to a named body, and report it publicly. The targets above reflect the best current science and the best current reading of Cascadia's hazard, and Section 5 sets the discipline for keeping them current. For that discipline to hold in practice, the task needs an owner. Vancouver should assign the annual review of the Coastal Resilience Safety Factor to a named body, whether a standing committee, a designated staff office, or an appointed third party, and require it to report to council each year on whether the climate range, the seismic probability, the subsidence allowance, or any other material input has moved. The review is annual; the committed design basis is not. As Section 5 sets out, a reported movement becomes a change to the standard only when it crosses the bounds already anticipated in the adaptation plan, and the change is then made deliberately, through the governance process that authorized the borrowing and on the monitored-trigger logic of Section 8, so that contractors, bond markets, and the voters who approved the programme build to a basis that moves on evidence and authorization rather than on the calendar. The same body revisits the consequence factor S only on its slower, consequence-triggered basis, never as a quiet response to budget pressure. That public record, accumulating year over year, is what converts a single calculation into the standing instrument Section 5 describes; a standard that belongs to everyone in principle and no one in particular is the most common way a living margin quietly hardens into a fixed and ageing one.

Finance the margin at the scale the hazard requires. Even priced as an all-protection response, the most capital-intensive lever and so an upper bound, the order-of-magnitude cost of the moderate standard is not the roughly one billion dollars the city has carried in its own reporting but a regional programme on the order of tens of billions, plausibly CAD 25 to 50 billion in current dollars for the moderate target and higher for the best-practice one (Section 7); the least-harm mix the paper recommends would be costed lever by lever, but no plausible mix returns the total to municipal reach. The city has stated that funding even its existing one-metre commitment exceeds its capacity; a programme an order of magnitude larger is beyond question a senior-government undertaking. Two steps follow: establish a dedicated, ring-fenced capital programme for coastal flood protection, distinct from the maintenance of existing seawalls; and secure from the provincial and federal governments a sustained multi-decade commitment, on the order of one to one and a half billion dollars a year averaged across the build-out, structured to buy protection before a catastrophe rather than relief after one. Because prevention early is cheaper than prevention deferred and far cheaper than recovery, this is the least-cost as well as the least-harm financing path.

Begin now; the start cannot wait for certainty. The most consequential recommendation is also the simplest. Because the programme must be built over decades and the hazard compounds every year, the binding decision is not how high to build but when to start, and the answer is now. As Section 8 sets out, major construction on the first and most exposed reaches must begin within roughly five years and a first tranche be operational by the mid-2030s; further delay does not buy better information that would change the standard, it only raises the cost of meeting it and the odds of being caught short. In concrete terms this is a charge to a specific body: the council elected in October 2026 should commission the costing, secure the senior-government cost-sharing, and prepare the borrowing authorization that the Vancouver Charter requires the electors to approve (s. 242), so that a funded, voter-approved programme can begin construction in the early 2030s rather than the 2040s. That mandate, however, reaches only as far as the city's own fiscal commitment: the borrowing by-law authorizes Vancouver to bind its own taxpayers, not to determine what happens on or to the lands and waters of the Nations whose territory the works would touch. Beginning while beginning is still the cheaper choice is the whole of the recommendation, and it is the one the engineering disciplines reached long ago about every margin that matters.

Decide the distributional question deliberately, and in partnership with the Nations. A margin financed and built still leaves the question of who is protected and who is asked to move, and a retreat left to the market sorts people by their means. That allocation should be made openly rather than by default, with explicit attention to where trapped-population risk concentrates. And because no adaptation strategy for this territory can be legitimately settled without them, the Musqueam, Squamish, and Tsleil-Waututh Nations should hold decision-making rather than advisory authority over the strategies, timelines, and thresholds that affect their lands and waters, an authority grounded, as Section 9 sets out, in provincial law as much as in ethics and effectiveness. Because those strategies, timelines, and thresholds are largely set during the planning phase this paper assigns to the council elected in 2026, that authority must be exercised concurrently with the municipal process, from the outset, rather than deferred to a later council or sought as consent to a plan already designed. The municipal borrowing mandate and the Nations' authority are not competing claims to a single decision: the first governs whether the city commits its own fiscal capacity, the second what may be done on and to Indigenous lands and waters, and a defensible programme is one in which each is exercised in its own domain and jointly where they meet.

Offer the method, not only the number, as a template for British Columbia's coastal jurisdictions. The framework's value is that it is general: any coastal community can enter its own climate range, its own subsidence or seismic exposure, and a safety factor scaled to what it stands to lose, and read out a defensible margin of its own. Vancouver is unusual in carrying a subduction-zone term, but the structure, hazard plus hazard multiplied by consequence, is portable. Adopting it would give the province a common and transparent language for coastal margin in place of a patchwork of single-projection freeboards calibrated, as Vancouver's now is, to budgets rather than to consequence. The procedure a jurisdiction would follow, identifying the drivers demonstrable on its own coast, entering each with its proper sign, and revising the calculation annually as the science and the planning horizon move, is the regional-application framework set out in Section 5.

The limits of this analysis. Several qualifications bound these conclusions. This is a work of synthesis and argument, not of primary research: it advances no new modelling, generates no new data, and performs no Vancouver-specific benefit-cost or pathways analysis.

Its quantitative claims are, with one deliberate exception, order-of-magnitude rather than precise: the multiplier of roughly 1.5 to 1.6, the cost-escalation figures, and the recovery-to-prevention ratios establish structure and scale, not exactness. The exception is the Coastal Resilience Safety Factor, whose arithmetic is carried to two decimal places to show the method faithfully; that precision belongs to the calculation, not to the hazard, and the targets it yields are only as firm as the driver ranges and safety factor entered into it. And because the paper applies the method only to Vancouver, where both drivers are uncertain and upward, the general apparatus the framework now carries, the rules for populating H on other coasts, the additive stopping rule, and the decomposition of S into an uncertainty premium and a set of target-level allowances, is set out in principle but exercised so far only on this first and simplest application; its behaviour on a coast that carries a well-constrained or sign-negative driver, where those distinctions actually bite, is argued rather than demonstrated, and a worked application to such a coast would be the natural test of the method's generality. Most of the economic and adaptive lessons it draws are transferred by analogy from settings that are not Vancouver: the New York Harbor study, a Hawaiian shoreline, six international cases, and a New Zealand drainage network. The principal exception is the governance diagnosis, where interview-based evidence specific to Vancouver's adaptation professionals corroborates the protect-default, the funding constraint, and the jurisdictional and political-will barriers this paper identifies (Doberstein et al., 2020); what remains transferred by analogy is the quantitative economic and pathways detail, not the political-economy diagnosis. As the paper states throughout, what transfers is the form of the trade-off, not the numbers. Some municipal figures rest on secondary reporting of council briefings rather than on primary documents. The compound-hazard claim that most distinguishes Vancouver's position leans heavily on recent modelling of Cascadia subsidence, though the underlying phenomenon is well attested in the paleoseismic record, and the temporal coincidence of earthquake and accumulated sea level rise, on which the worst case depends, is genuinely unknown rather than merely uncertain. Finally, the treatment of Indigenous rights is necessarily written from outside: it argues for Nation-led authority but cannot stand in for it, and should be read as a case for that authority rather than an exercise of it.

Wildlife and ecosystem protection. One further boundary deserves to be named explicitly, because its absence from the calculation is deliberate rather than an oversight. This paper does not treat wildlife and ecosystem protection as a primary consideration, though these are critical to any honest coastal adaptation strategy and central to the values many jurisdictions hold for their coasts. The Coastal Resilience Safety Factor is a framework for calibrating a design margin to physical hazard and consequence; it is not a decision tool for what to protect or for how ecological values should be weighed against other uses. A jurisdiction adopting the method must integrate its own ecological priorities, its species-at-risk obligations, and its habitat-protection goals into the consequence factor S and into the choice among levers. Nature-based solutions and wetland accommodation, discussed in Section 5, are one pathway through which ecological protection can be operationalized within the framework, but the paper does not prescribe how. We recognize, moreover, that incorporating wildlife and ecosystem protection as explicit priorities would likely push the consequence factor S higher than the values applied here, since such protections add both to what stands behind the margin and to the cost of the response. This is properly a matter for each jurisdiction, and the Indigenous Nations whose territories are at stake, to determine.

Directions for further work. The most valuable next step would be to do for Vancouver what this paper argues for in principle: a quantified, spatially explicit adaptive-pathways analysis across the eleven coastal zones, with monitored triggers, explicit lead times, and a least-harm comparison that prices all four levers separately for the dense core and the agricultural margin. Such an analysis would convert the framework defended here into a working decision tool. Five further lines would reinforce it. First, compound-hazard modelling specific to the Lower Mainland, coupling Cascadia subsidence scenarios to climate-driven rise on the Fraser, would replace the present qualitative coupling with a joint distribution a planner could act on. Second, a distributional study of where trapped-population risk concentrates within Metro Vancouver, together with the financing mechanisms by which senior governments might fund prevention before disasters rather than recovery after them, would begin to close the governance gap this paper identifies but does not solve. Third, and indispensably, research conducted in partnership with and under the authority of the three Nations is needed to define the cultural-site and food-sovereignty thresholds any honest trigger-based plan must respect. Fourth, the Canadian evidence base itself needs building. The economic comparison this paper has leaned on throughout, weighing sustained protection against staged retreat in net-present-value terms, has been worked out for coasts in the United States and New Zealand but not for a Canadian one. The country has not ignored the economics of managed retreat: a recent British Columbia assessment works carefully through both cost-benefit and multi-criteria decision analysis for community-led retreat, drawing on buyout experience at Grand Forks, Merritt, and elsewhere (Cross et al., 2024). But every Canadian case it documents is inland and riverine rather than coastal, and the formal economics were narrow and reactive: at Grand Forks the only assessment was a return-on-investment calculation prepared to satisfy a federal funding application, with no comparison against alternative strategies; at Merritt, full floodplain retreat was scored against diking options but not selected. That same review stresses how little of the relevant ledger such assessments capture, the avoided perpetual maintenance of protective works, the flood-buffer and ecosystem value of land returned to nature, and the social cost of displacement among them, recognized as decision-relevant yet left unmonetized or treated only informally (Cross et al., 2024). The Canadian evidence base is thus inland, reactive, and funding-driven, with no coastal, proactive, sea-level-rise comparison of the sort this paper has had to import from Los Angeles, a Hawaiian shoreline, and a New Zealand coast. Building one for a Canadian coast, with the non-financial costs the existing tools omit, would give British Columbia decision-makers an evidence base of their own rather than one borrowed from abroad, just as the construction-inflation and recovery-multiplier figures would be stronger rebuilt on Canadian data. Fifth, and institutional rather than empirical: a defence mounted by Vancouver alone, however well calibrated, cannot secure a shoreline that is continuous and a hazard that is regional, so the mechanisms for coordinating adaptation across the Metro Vancouver municipalities, and across the several Nations whose territories the regional coast and the Fraser estuary traverse, are themselves a necessary subject of study.

A final direction looks past Vancouver to the method itself. The Coastal Resilience Safety Factor calibrates a margin to consequence and keeps it current; it is indifferent to how that margin is paid for. Vancouver's case rests on voter-approved borrowing under the Vancouver Charter, but that is one financing model among many, and the diversity is vast: general revenues, provincial or federal cost-sharing, international climate finance, public-private partnerships, regional authorities, and Indigenous co-governance arrangements, with some jurisdictions requiring a referendum and others not. No single rubric could capture that variety, and this paper does not attempt one; the mechanisms that turn a calibrated target into built infrastructure are for each jurisdiction, and the civic governments, regional authorities, and Indigenous bodies that hold authority over land and money within it, to navigate in the ways they know best. A valuable line of work would be comparative rather than prescriptive: documenting how different funding and governance models affect the timeliness and adequacy of margin-building, so that jurisdictions adopting the method can learn from one another's financial and political solutions, and not only from its engineering logic.

None of these directions would overturn the paper's basic finding; they would sharpen and localize it. The gap between what engineering ethics would assign to a consequence of this magnitude, under uncertainty of this depth and compounded by a hazard peculiar to this coast, and the routine-grade margin the region now implements, is wide, and it is widening as the science advances and the politics of mitigation weaken. Closing it is not, in the end, a technical problem; the technical case for a larger, layered, monitored margin is already clear. What remains is the harder work of financing that margin and governing it justly, and of beginning while beginning is still the cheaper choice.

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