Economic Assessment and Decision-Making for Community-led Managed Retreat in British Columbia:

Approaches, Challenges, and Case Studies of Cost-Benefit Analysis and Multi-Criteria Decision Analysis

PICS

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Managed Retreat may be considered by any community within British Columbia. In this context, Living with Water and the specific authors of this article pay our respects to the Elders, past and present, descendants and custodians of the traditional territories of Indigenous nations throughout British Columbia. We honour the knowledge keepers and the continuing relationships with Indigenous peoples and the land and waters in BC.

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Executive Summary

What is Managed Retreat?

Managed Retreat is a form of natural hazard risk reduction that involves the strategic relocation of people and structures out of harm's way, often accompanied by ecological restoration and a permanent change in land use.

While Managed Retreat can be used in response to a range of natural hazards, **this report focuses on its use as a community-led form of flood risk reduction in British Columbia.** However, the key principles and approaches discussed within should also help to inform Managed Retreat decision-making for other hazards, such as wildfire and landslides.

What Makes Managed Retreat Unique?

Managed Retreat offers many potential **advantages** over traditional structural flood protection strategies, including:

- the removal of residual flood risk
- avoiding the impacts of future flooding
- providing a range of flood protection, environmental, and cultural benefits to surrounding areas
- offering an opportunity to address other societal goals and inequities through dramatic land use change

However, relocating households and neighborhoods can also lead to distinct impacts and **concerns**, such as:

- disrupting communities and sense of place
- higher upfront costs
- equity issues
- forcing participants to go through complex bureaucratic procedures

The unique aspects of Managed Retreat mean that traditional decision-making focused on technical and fiscal aspects is likely to omit or inappropriately assess important values and considerations, potentially leading to Managed Retreat being dismissed as a valid option, or implementing retreat in ways that have unintended negative consequences.

Structure of Report

When designing and implementing cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA), two of the most commonly used decision-making tools (see Section 3), it is important for analysts and decision-makers to understand the full breadth of benefits and challenges involved in Managed Retreat (see Section 2) to accurately assess retreat as a risk reduction strategy.

The Managed Retreat literature and relevant case studies reflect a reoccurring theme that there is no one-size-fits-all approach to assessing and making decisions (see Section 4). However, a number of key principles have been identified, which have been used to create a framework for designing assessment and decision-making processes. An extended list of these key principles can be found in Section 5 and the framework for Managed Retreat decision-making can be found in Section 6, but the most important aspects are summarized below. A two-page brochure that outlines the key findings in this report is also available in Appendix 6.

Key Findings

The assessment and decision-making processes for Managed Retreat should be designed for the specific context and nature of the decisions being made. For example, these processes may be very different for a community deciding whether to proceed with retreat, a municipal government selecting amongst multiple flood risk reduction options, a higher level government deciding if retreat is best for society as a whole, or when fulfilling the requirements of a flood risk reduction funding application. An assessment meant for one decision may be inappropriate for another context, even for the same retreat project.

Any assessment, whether using CBA, MCDA, or other tools, should only ever be one input to a larger decision-making process, and not used as a standalone decision rule. **The assessment process is often more valuable than the final outcome**, and the process should be designed to maximize these process benefits.

Community engagement and co-production is close to a universal recommendation in the Managed Retreat literature. **The community should be involved as fully and at as many stages as possible** in both developing and executing the decision-making and assessment processes for Managed Retreat.

2

Background

2.1 Introduction

Compounding climate and societal factors are driving a need for innovative flood risk reduction approaches in many British Columbia communities. These factors include:

- increasing hazard, climate variability, and uncertainty due to climate change
- decreasing societal acceptance of risk, disruption, and loss from natural hazards
- increasing losses from disasters due to economic growth and development
- increasing recognition of inequities in the distribution of flood risk, flood impacts, and the impacts of traditional flood risk reduction measures
- greater concern for the environmental and social impacts of the structural flood risk reduction measures that have traditionally been favored

Reducing flood risk can be done using various approaches, including protection, accommodation, retreat, and avoidance (PARA)[1], each of which can take many forms and be used individually or in combination. Managed Retreat, **which involves the strategic relocation of people and structures out of harm's way, often accompanied by ecological restoration and a permanent change in land use**, has received increasing attention in recent years as a potential option for the highest risk areas where more traditional approaches are no longer viable. However, Managed Retreat presents a series of unique challenges that make it difficult to decide when and where it should occur, and how it should be implemented to minimize negative impacts on households and the community, and to maximize its potential to address inequalities and to provide ecosystem and other co-benefits.

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Living With Water (LWW) was funded by the Pacific Institute for Climate Solutions (PICS) partially to begin resolving these planning and decision-making challenges around Managed Retreat. In addition, the Province of B.C. provided funding for research into the nature of the decision-making challenges associated with Managed Retreat and the tools available to overcome them, such as cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA). In particular, **the Province is focused on how to use Community-Led Managed Retreat as part of the broader suite of tools available to manage flood risk in B.C., as described in Actions 2.9, 3.4, and 4.5 of the B.C. Flood Strategy**. This report summarizes that research and describes the wide array of values and impacts that should be assessed when a community is considering Managed Retreat as part of a flood risk reduction strategy.

Managed Retreat can occur in many forms, with many potential variations, including: when it occurs (e.g., proactively pre-flood or reactively post-flood); its scale (e.g., at a neighborhood/community scale or at a building-by-building level); how it fits into wider flood management planning (e.g., as the main risk reduction strategy, as a part of an integrated flood management plan, or to acquire land needed to construct other flood mitigation works); who initiates it (e.g., community-led, government initiated); who funds it; the level of compensation offered to property owners; the types of supports offered to participating households or communities; and, what happens to the lands following retreat.

Contested Terminology

Managed Retreat goes by many different names, including: strategic retreat, planned relocation, transformative adaptation, managed realignment, and others. Different terms have been used to specify particular forms of Managed Retreat, or to avoid public opposition due to negative experiences in previous retreat programs and ingrained resistance to the idea of "retreat".

At their core all these terms focus on the same concept – moving people and structures out of harm's way – and the information in this report can apply to all forms and variations of Managed Retreat in support of natural hazard risk mitigation. Similarly, **the general term 'Managed Retreat' is inclusive of the community-led programs that are the focus of the Province of B.C.**

Another key characteristic of Managed Retreat programs is whether or not it is voluntary for the affected households or communities. Due to the long history of forced relocation and displacement in the context of colonization and industrialization, non-voluntary Managed Retreat can raise many sensitivities and concerns among affected communities. While most Managed Retreat programs today are either voluntary or initiated by the community itself, there are cases when expropriation or other non-voluntary mechanisms are used for Managed Retreat, particularly when it is needed to maintain public safety by removing households from high-risk environments or to create room for flood protection infrastructure.


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While Managed Retreat offers many potential advantages over flood protection, it also has a range of impacts – both positive and negative – that are not easily captured in assessment and decision-making. To aid in the design of future Managed Retreat decision-making processes, this report aims to provide:

- a primer on the challenges associated with Managed Retreat and Managed Retreat decision-making (Section 2),
- an overview of economic assessment techniques for climate change adaptation and flood risk reduction projects, focusing on two of the most commonly used approaches: cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA) (Section 3), including a review of factors that may be required for the assessment of Managed Retreat programs (Section 3.1.2),
- a review of recent economic assessment of Managed Retreat proposals and other related case studies and examples (Section 4), and
- a summary of key principles for Managed Retreat assessment and decision-making (Section 5)
- a newly created framework based on the key principles for designing the assessment and decision-making processes for projects involving Managed Retreat (Section 6)

Cost-Benefit Analysis (CBA): Compares the total anticipated costs and benefits (all converted to monetary values) for each proposed alternative to determine which has the greatest net benefit to society, or to select all options with a positive net value.

Multi-Criteria Decision Analysis (MCDA): A broad group of tools and approaches used to evaluate, discuss, and rank alternative options by considering diverse qualitative and quantitative factors and their relative importance in a systematic way.


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2.2 Managed Retreat as an Adaptation to Flood Risk

Although this report focuses on the process of decision-making, it is important to understand the full range of opportunities and challenges that Managed Retreat presents, and how the impacts of Managed Retreat often differ from traditional forms of flood risk reduction. Having a better understanding of Managed Retreat will help to design a decision-making process that considers the full range of potential impacts. Please see Appendix 2 for more information on specific tools and approaches available to address the Managed Retreat decision-making challenges discussed below

2.2.1 Benefits & Opportunities of Managed Retreat

Hazard Elimination

Managed Retreat's primary advantage is the complete elimination of hazard exposure at the project site via removal of people and infrastructure from harm's way. Eliminating the hazard prevents subsequent infrastructure damage, disaster response and recovery costs, loss of life, environmental pollution, and psychosocial impacts and trauma of experiencing a flood[2]. This contrasts with structural flood protection: many flood protection evaluations assume 100% efficacy up to the designed protection level, but there will always be a chance that the protection will fail, severe events will over top the infrastructure, or climate change will render the protection insufficient.

Avoids Negative Impacts of Flood Protection

Reducing or eliminating the need for structural protection avoids the associated negative impacts of flood structures, including: residual flood risk[4]; high construction and maintenance costs[5]; negative effects on erosion, sediment transport and ecosystem loss[5]; the 'levee effect' where development and hazard exposure increase behind protection infrastructure due to a feeling of safety[2]; the creation of physical and emotional barriers between communities and the water[6,7]; and, the additional land needed to construct protection structures.

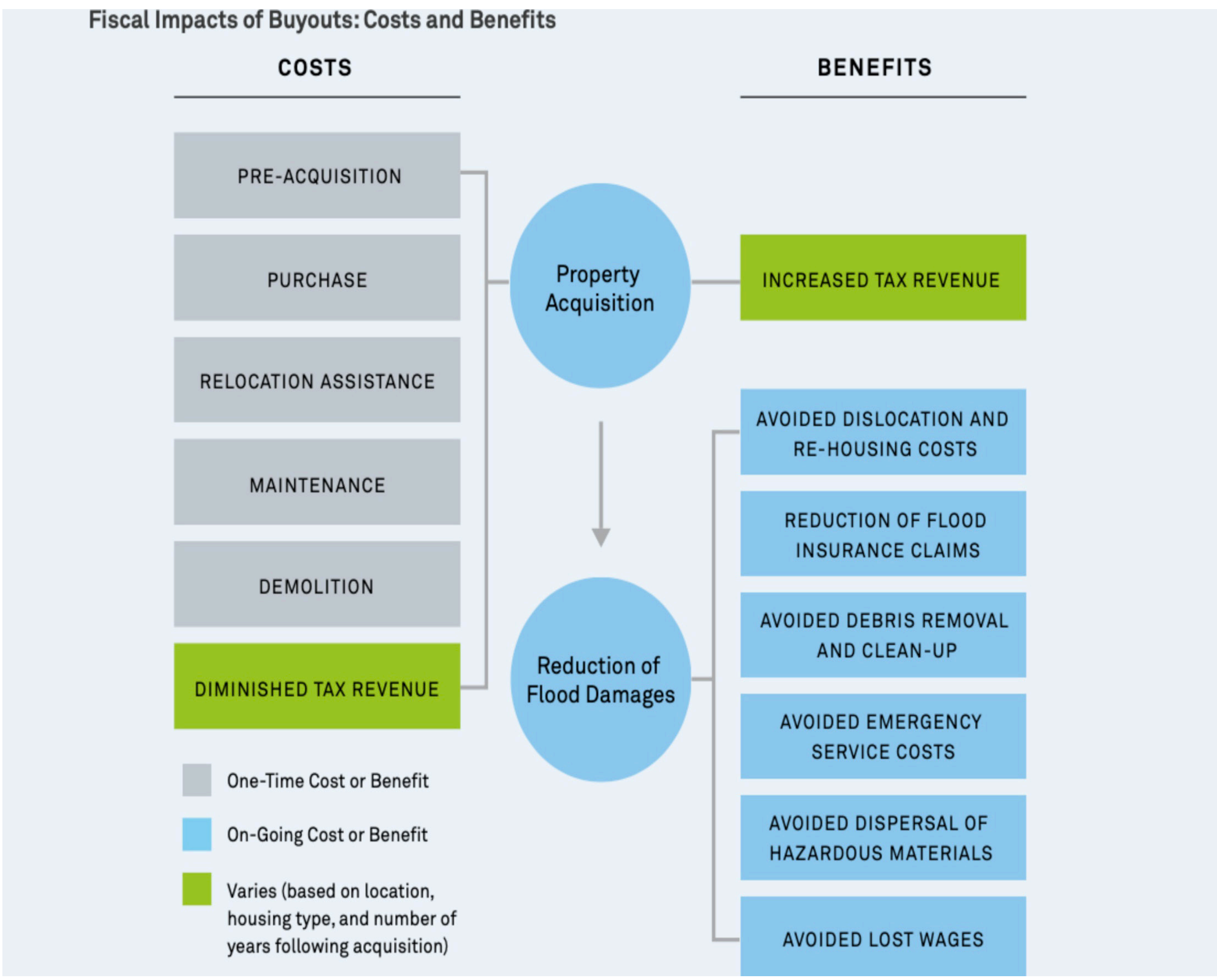

Figure 1: Summary of basic financial costs and benefits of Managed Retreat. From Freudenberg et al., 2016.[3]

Broad Ecological and Social Benefits of Retreat Lands

Unlike protection and accommodation measures, which are at best neutral to adjacent areas, **Managed Retreat provides benefits to neighboring areas** in the form of possible enhanced recreation, flood protection, beautification, ecosystem benefits, and cultural opportunities[7,8]. Managed retreat may also include the purchase and removal of buildings to facilitate the construction or upgrading of flood protection infrastructure, also contributing to wider flood protection benefits.

Broadening the Solution Space

Even if Managed Retreat is not optimal today, planning for a future where flood protection may no longer be technically, economically, or climatically feasible can reduce lock-in and path dependencies[9] (i.e., when previous actions constrain future options, such as allowing further development behind a dike leading to demands for ever higher dikes), minimize trauma and lost opportunities from post-disaster retreat[10], and help identify creative community solutions by facilitating discussions about trade-offs and the community values that are, or are not, worth protecting[7].


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Transformational Change

By fundamentally changing land use, voluntary Managed Retreat may be well suited to address the foundations of vulnerability [11] and historical legacies of racism, colonialism, forced relocation, and discrimination that either removed Indigenous groups from their lands or resulted in disadvantaged populations being disproportionately represented in high-risk areas[12–14].

2.2.2 Challenges to Managed Retreat

Contested Goals and Objectives

A key challenge for Managed Retreat is the lack of agreement on what it means for retreat to be successful[2,15]. While early buyouts focused on technical, managerial, and compensation targets (e.g., number of buildings removed, acceptable compensation schemes), more recent programs often consider other factors and forms of success such as fostering equitable outcomes, empowering communities, restoring ecosystem function, or effecting systemic change to address inequity, reconciliation, and injustice[15–17].

Even using basic risk reduction metrics, it is also unclear if Managed Retreat consistently decreases household or community vulnerability[18]. This is partly related to data gaps from poor record keeping and a lack of post- buyout studies[12,19], but there is evidence of mixed or even negative impacts of retreat on vulnerability. For example, one study found that, of relocated households studied post-Hurricane Sandy, over 20% moved to another area exposed to coastal flood hazards and 99% relocated to areas of higher social vulnerability[20].

Clarity and agreement on the objectives and priorities of a Managed Retreat program is vital for successful planning, assessment, decision-making, and implementation. Prioritizing different objectives can lead to assessing different values (e.g., prioritizing community values or financial impacts of flood damage and recovery) or assessing those values in a different way (e.g., using pre-flood or post-flood property valuations), which can lead to substantially different outcomes.

Implementation Issues and Poor Experiences

Where Managed Retreat has been implemented, participants have reported several common issues, some of which can have substantial, long-term impacts on quality of life, including:

- long timelines to complete the process, causing issues with insurance claims or being forced to remain living in high-risk areas or precarious circumstances[13,21]
- insufficient compensation to relocate to areas with lower social and natural hazard vulnerabilities[20]
- poor communication and lack of transparency in program planning and implementation[14]
- pressure to accept buyout offers in purportedly voluntary programs[14,22]
- arbitrary damage thresholds that limit choices to stay or leave [14]
- seeing abandoned properties re-developed or used to benefit neighboring wealthy areas[23]
- post-buyout patchwork neighborhood patterns (aka "swiss cheese effect") causing decreased or more expensive infrastructure maintenance and loss of sense of community[19]

Additional planning challenges that affect whether Managed Retreat occurs and if objectives are successfully met include:

- high buyout costs and difficulty obtaining funding due to a lack of funding sources that include property buyouts, and a large administrative and financial burden on local governments to plan retreat programs and navigate funding program requirements [4,6]
- balancing timeliness in post-disaster buyouts with adequate community engagement[19]
- tensions between a need for high level guidance and consistency vs. community-specific needs[16,24]
- finding available land and/or housing for relocation[5,25]
- decision-making under contested objectives, different conceptions of success, and uncertainty[11,26]
- potential impacts to agricultural lands and livelihoods, and food production and security

Equity Concerns

The distribution and characteristics of the locations where Managed Retreat is most likely to be needed, and where it ultimately occurs, raises several equity concerns that should be considered when designing and assessing retreat programs. For example, in the United States, even though buyout programs are more often initiated in wealthier and 'whiter' communities that have the resources to access federal funding and manage the complex planning involved, the households that qualify for and accept buyouts are predominately in poorer, more racially diverse, and socially vulnerable neighborhoods[12,14,19]. This finding points to potential equity issues in both buyout program accessibility and in who is directly affected by buyouts when they do occur. Several potential explanations have been proposed that raise equity and justice concerns, including:

- the prioritization of wealthier neighborhoods for expensive structural protection, whether due to political influence, the perception of having assets that are more valuable to protect, or other biases[12]
- reduced 'voluntariness' of buyouts in lower income and vulnerable neighborhoods due to these areas having fewer options and less flexibility[22]
- lower income and minority communities being located in flood-prone areas due to histories of racism, colonialism, forced relocation, or these communities being financially limited to living in higher risk areas[2,12]
- the Federal Emergency Management Agency's (FEMA) 'substantially damaged' criteria and the property value threshold (where buyouts are assumed to be cost-effective) being more easily reached for lower-value homes [14]
- 'green gentrification' where low-income neighborhood buyouts create amenity space for adjacent wealthier communities[4]
- retreat programs commonly lack supports for renters who are commonly lower income and are left without a home when buyouts occur. Residents of mobile home parks may also have distinct vulnerabilities that require additional supports

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Lower income, minority, and Indigenous communities also typically have more difficulty accessing government funding and support when actively seeking relocation (e.g., Isle de Jean Charles, Louisiana, and Shishmarif and Newtok, Alaska)[2,17,27]. Buyout programs that target individual households, rather than entire communities, can make it difficult for Indigenous communities to access relocation funding, and for tightly knit communities to maintain social capital and cohesion during relocation[17,27].

Overall, it is not clear if Managed Retreat is working as intended, by removing vulnerable people and exposed properties from hazard exposure, or if certain groups are being unfairly targeted and influenced to participate in buyouts, which may or may not decrease hazard exposure and vulnerability[16].

If maintaining or improving equity is an important objective, then the design, assessment, and decision-making processes needs to have a clear equity focus since it takes particular attention and effort to measure equity-related impacts and to design risk reduction strategies that address the needs of the specific community.


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Public Opposition

Managed Retreat has become so controversial in some communities that it is difficult or impossible to discuss[28]. Many factors have contributed to this, including:

- raising difficult conversations around values and what can or cannot be protected[29]
- the concept of 'retreat' being associated with 'giving up' and going against a sense of 'toughness'[23]
- misperception of hazard risk[30,31] and perceived threats to real estate values, particularly for high-value waterfront properties[32,33]
- questionable compensation fairness, which can be seen as either a wealth transfer to the affluent who knowingly took on risk[14,34] or insufficient compensation for households in need, depending on the context
- poor participant experiences and lack of post-relocation supports in previous buyouts[7,16,23]
- strong sense of place[7,35] and fears of community erosion and patchwork retreat patterns[7,23]

These concerns can make it politically risky to discuss Managed Retreat as there are significant political incentives to accede to pressure from the community, real estate, and other vested interests[28,36,37]. These issues are exacerbated by government-run, non-risk-based insurance programs that incentivize building and living in high-risk areas[4,31], and trade-offs between long-term community planning and short-term political thinking[28,36,37]. To hear and address these types of issues, planning and implementing Managed Retreat may require a substantial and lengthy engagement period that should be incorporated in the assessment and decision-making processes.

Proactive versus Reactive Retreat

Most examples of Managed Retreat in Canada and the USA have occurred reactively, in the aftermath of a large flood event[38,39] (e.g., Hurricane Hazel[1], Pointe Gatineau and Constance Bay[24], Grand Forks[40], Calgary and High River[41], and Hurricanes Sandy and Katrina[38,42]). However, **there is evidence that proactive retreat programs are more likely to be successful[15,43]** and there is documented support for proactive, government-funded buyouts in flood prone areas[44], especially for expected climate change.

Proactive retreat allows for logistical, economic, socio-cultural, and justice concerns to be addressed more effectively[15] and comprehensively, and avoids an extensive list of challenges and negative impacts associated with post-disaster retreat, including:

- all of the impacts of experiencing a flood, including: psychological stress and trauma[10]; emergency response and clean-up costs[45]; environmental contamination[32]; loss/damage of resources that could have been relocated[10]; injury and loss of life[46]; temporary loss of livelihoods; and, major life impacts, such as triggering homelessness[47]
- forgoes the flood protection benefits provided by the naturalized floodplain[4,48]
- lack of time and resources for communication, engagement, and co-production of retreat planning [23,38]
- long delays between a flooding event and concluding a post-disaster buyout[32,49]


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Despite the many potential benefits of proactive Managed Retreat, there are many challenges to its implementation and there is conflicting opinion on whether it is a realistic objective in most contexts. Obstacles to proactive Managed Retreat include:

- difficulty setting triggers or tipping points to initiate retreat[50–53]
- perceptions of retreat as a high-regret option in the face of uncertain climate change[2,54]
- mismatched incentives in planning horizons for politicians, real estate interests, communities, and individual households[37]
- lack of funding mechanisms[6] , and those that do exist tend to be discretionary (i.e., made available on a case-by-case basis), leading to a need for a triggering event to gain support[18]
- lack of local capacity, decision-making tools, and guidance to implement complex, multi-year retreat programs[4]

Collaborative and creative flood risk reduction planning, funding, and decision-making processes could help to overcome these challenges and increase the chance of successful, proactive Managed Retreat programs in appropriate areas. Alternatively, early 'pre-planning' and engagement will tend to minimize the negative aspects of reactive programs even if Managed Retreat is implemented post-disaster.

3

Assessment Tools for Managed Retreat Decision-Making

The issues discussed above, in addition to the highly technical, long lasting, and uncertain nature of flood risk management and climate change adaptation planning, bring a high level of complexity to Managed Retreat decision-making. As humans can only consider a limited number of factors at one time, aids and tools are needed to effectively understand more complex situations[55]. Using established and holistic assessment tools can help to facilitate the comparison of different options and trade-offs[55,56], improve understanding and communication[56,57], and increase transparency[58,59].

The following section focuses on two of the most common economic assessment and decision support tools used in flood risk management and climate change adaptation: cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA)[57,60,61].

Key differences between the two tools include:

Cost-Benefit Analysis (CBA)	Multi-Criteria Decision Analysis (MCDA)
Focuses on finding an economically-optimal solution	Puts more emphasis on facilitating discussion and understanding amongst participants
Requires the monetization of all included costs and benefits	Can accommodate a range of qualitative and quantitative (both monetary and non-monetary) costs and benefits
Assumes that all participants in the process assign the same weights/priorities to the various costs and benefits examined, as expressed by the monetary valuations assigned and simple summation of these values	Weights are assigned to each factor and/or group of factors to represent different levels of importance and priority. This process allows for examinations of how the outcome would change when using different weights/priorities (e.g., recalculating the outcome using the suggested weights from each participant, testing the result of assigning the cost criteria a weight of zero)
Typically more rigorous than MCDA in its treatment of uncertainty and discounting, and it can accommodate and provide a greater level of precision compared to MCDA	Less rigorous than CBA in its treatment of uncertainty and discounting, and it can't accommodate or provide a greater level of precision compared to CBA

It is also important to note that CBA and MCDA are not competing tools but are often used in tandem, with a CBA representing the monetary costs and benefits in an MCDA. The MCDA process is then used to explore other factors that the participants decided were not appropriate to monetize.

3.1 Cost Benefit Analysis of Climate Change Adaptation and Flood Risk Reduction

3.1.1 Introduction

In its idealized form, the aim of CBA is to identify the course of action that maximizes total societal welfare by assessing all of the costs and benefits of each option available by converting the wide range of potential impacts to a common, monetary measurement[56,62]. In practice, CBAs are typically more limited in scope to the costs and benefits that can be easily measured or that are deemed to be most important to the decision.

The detailed methodology of CBA is beyond the scope of this report, but broadly the steps involved include:

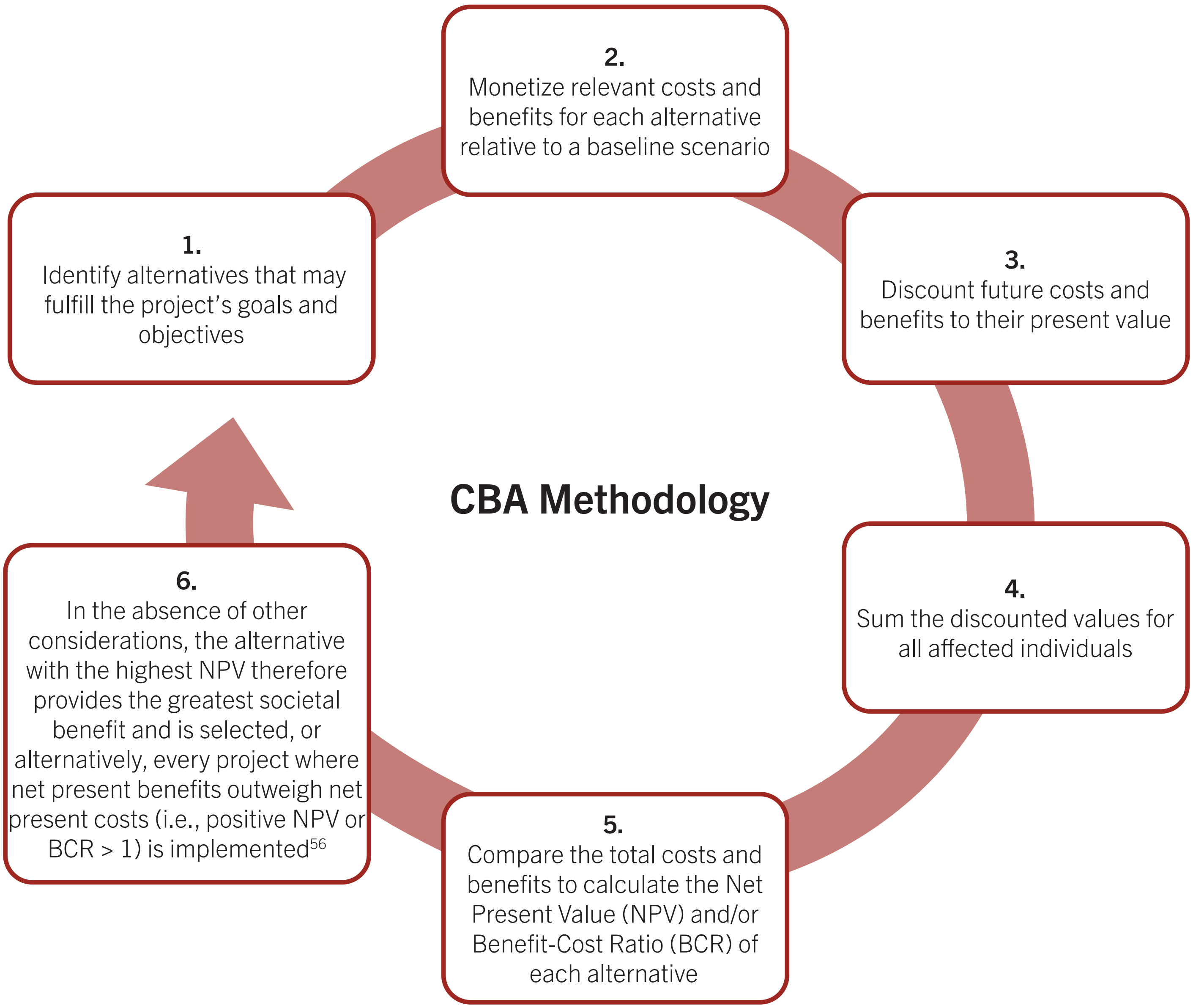

Figure 2: Cost-Benefit Analysis (CBA) Methodology. Cross, 2024

The remainder of Section 3.1 focuses on features and challenges specific to CBAs of Managed Retreat. For additional resources on CBA methodology for flood risk reduction and climate change adaptation, please see the list of reference documents in Appendix 1.

3.1.2 Measuring Costs and Benefits of Managed Retreat

This section summarizes the major categories of Managed Retreat costs and benefits considered in CBAs, and common approaches for measuring them. The list of impacts below is not meant to be exhaustive, but instead highlights where Managed Retreat may differ from other flood risk reduction and climate change adaptation projects. For a more a detailed list of factors that could be considered when evaluating Managed Retreat please see Appendix 5, as well as the thesis document Managed Retreat Components And Costing In A Coastal Setting, and the National Research Council guidance document described in Appendix 1.

Reduction of Average Annual Damages

The main benefit of most flood risk reduction programs is measured in the reduction of expected flood damages to buildings and infrastructure over the lifespan of the structure or program. As flooding is intermittent and uncertain in any given year, a statistical approach based on our understanding of different flood depths and probabilities is used to estimate the average amount of damage expected per year over a long period of time, known as the Average Annual Damages (AAD). By calculating AADs both with and without the proposed risk reduction measures, it is possible to estimate the damages each option would prevent over their lifespans.

Estimating flood damages for different flood depths can be accomplished through either a 'top down' or 'bottom up' approach. 'Top down' approaches use historical, real-world measures of flood damage from insurance or other datasets and apply scaling factors to estimate damages at different flood depths and locations. This approach can be relatively simple but requires a thorough understanding of the data available, assumptions involved, and scaling factors (e.g., wealth, gross domestic product, new development). Also, as uninsured losses are usually not reported, insurance data must also be scaled to include all relevant damages, which can be up to 2.5 times insured losses[63].

'Bottom up' approaches use depth-damage curves and local hydrologic and hydraulic modeling to estimate and aggregate damage to individual buildings. This approach can be more accurate, especially where historical flood data is limited or where development has or is expected to substantially change the values at risk, but it requires technical expertise and high-quality data on the area's buildings and infrastructure.

Selecting an AAD method will depend on the resources and data available, and the level of effort should be commensurate with the scale of the project. It is also possible to use both 'top down' and 'bottom up' approaches, which can reduce uncertainty by finding where the two methods converge.

Buyouts and Land Use Changes

Managed Retreat's primary monetary cost is typically the initial property purchase and the associated loss of that land for residential, commercial, or infrastructure use. Estimating this cost (i.e., the compensation paid to homeowners in the retreat area) can seem simple, but how it is valued and estimated depends heavily on the retreat program's design and objectives, and on deeper conceptions of land value.

Factors that may affect how properties are valued or the level of compensation provided include:

Measurement Objective: Whether the goal is to measure the monetary program cost (i.e., the money necessary to purchase the property) or the loss to society associated with changing land use (e.g., market prices may not reflect the true value to society when real estate markets may be skewed by speculation or misperception of risk), or another project-specific value.

Reasons for Higher Compensation: Higher compensation levels may be provided if there is a need or desire to address equity impacts/concerns, increase community acceptance and participation, limit holdouts, maintain political viability, cover additional relocation costs, support broader community benefits (e.g., providing room for the construction or upgrading of flood protection infrastructure), and/or increase the likelihood of finding an equivalent home in a lower risk area, either in the same or different community. However, higher compensation rates can reduce the number of properties that can be purchased if budgets are limited, can be seen as unfair compensation to often wealthy homeowners who took on risk, and can lead to speculation and profiteering.

Compensation Caps: Caps on compensation per property may be put in place at the program or funding agency level due to budgetary restrictions, to reduce the perception of compensating wealthy homeowners, and/or to reduce speculation and profiteering. However, inadequate compensation caps can also prevent participating households from being able to afford equivalent or safer housing in the same community or another equivalent neighborhood, and reduce voluntary buyout uptake, leading to patchwork retreat patterns or the need for expropriation.

Effect on Program Outcomes: The base valuation method used to establish homeowner compensation levels will depend on program objectives and resources available, but this choice can have a substantial impact on program outcomes for participating households. Pre-flood value, post-flood value, tax value, and equivalent replacement value are all techniques that have been used in past retreat programs, with each resulting in different compensation levels depending on the local real estate market, degree of flood damage, perceptions of flood risk, and the nature of other planned flood mitigation works. Compensation substantially below what is needed to relocate to an equivalent home within the same community can effectively lead to eviction from the community, and is more likely to have a greater effect on lower wealth households which do not have the resources to compensate for low valuations.

Existing vs. New Assessments: Using existing tax assessment or market data is convenient and provides transparency, but can be skewed by market changes since the last assessments, or sales and any bias within the initial valuations. Conducting new assessments (whether using pre- or post-flood conditions) or evaluating the cost of equivalent homes in the community can take time, and will have a cost, but may result in more accurate valuations and provide an opportunity for input from the affected community.

Other Commonly Monetized Program Costs and Benefits

Common Monetary Program Costs	Common Monetary Program Benefits
• Planning and design • Communication and public engagement • Building and infrastructure demolition and cleanup • Acquisition of lands to relocate buildings and/or infrastructure • Post-retreat supports for affected households & providing temporary housing • Rehabilitation of retreat lands (e.g., ecosystem enhancements, recreation infrastructure) • Maintenance of retreat lands • Monitoring programs to identify triggers for future retreat • Economic and livelihood impacts from loss of commercial, industrial, or agricultural lands	• Reduction in infrastructure maintenance (e.g., roads, water and sewer pipes) • Reduction in emergency response and disaster recovery spending • Reduced flood risk for adjacent areas • Increased real estate value for adjacent areas (e.g., due to lower flood risk, other buildings become "waterfront", new natural and recreational amenities)

Non-Market and Intangible Impacts

The following impacts may or may not be included in a CBA, depending on the values and perspectives of the community, the decision-making context, and the information available (See Section 3.1.3).

Potential Non-market and Intangible Costs of Managed Retreat	Potential Non-market and Intangible Benefits of Managed Retreat
• Loss of sense of place and/or community • Disruption to work and personal relationships • Stress of relocating to a new home • Stress and uncertainty between flood event and buyout completion for post-disaster retreat • Loss of trust in government and other organizations, if retreat implemented poorly • Reduced or lost access to traditional lands (e.g. relocating an entire community to a new area)	• Enhanced ecosystem health and related ecosystem services • Recreational opportunities (e.g. green space, walking paths) • Increased connection to water/nature • Opportunities for cultural learning, recognition, and support (e.g., art installations recognizing area's history, reestablishing food harvesting practices, educational signage) • Decreased psychological and related harms from experiencing a flood • Decreased fear and stress from living in a flood-prone area • Increased access to traditional lands (e.g., removing coastal private properties can restore and enhance public access to coastal areas and ecosystems)

3.1.3 Challenges and Special Considerations for CBA of Managed Retreat

Value Section and Monetization

Compared to structural flood measures, Managed Retreat decision-making often emphasizes factors that are difficult to monetize, such as sense of community, attachment to place, and ecological benefits of floodplain restoration. Decisions about which factors to include in a Managed Retreat assessment and how each should be measured is a subjective decision that will depend on the nature of the program, the program goals, resources available to conduct the assessment, and, most importantly, on the values and priorities of the affected community. **Wherever possible, these decisions should be made through deep community engagement to ensure that the analysis outcomes represent the community's values and are as relevant as possible to the decision being made.**

For example, "increased wetland area" might be omitted in an assessment where little change is expected, monetized in another assessment where the community's values align with easily monetized ecosystem services and recreational opportunities, or included as an entire category of qualitative and quantitative indicators in an MCDA if there are many different physical and cultural values at play.

Non-monetized factors must be considered elsewhere in the decision-making process, which has led to many non-market factors being effectively ignored in flood management decisions. This can be mitigated through the careful design of the decision-making process and transparency in the CBA methodology.

> Techniques to monetize non-market impacts include: Willingness to pay or accept (WTP, WTA) surveys and choice experiments; Ecosystem service estimates; Travel cost and replacement cost assessments; Benefit transfers approaches, and market proxies and substitutes. See Appendix 5 for more information.

It should also be noted that these challenges are not unique to Managed Retreat. Assessments of other flood risk reduction measures often ignore potentially significant costs and benefits that are difficult to measure or monetize, such as the psychological and health effects of experiencing a flood. It is therefore important to understand what is and is not included in a given assessment when comparing results across studies.

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Indigenous Values and Substitutability

The issues of non-market valuation are particularly apparent when CBA is applied to Indigenous values since the concepts of individual utility maximization and aggregation, which are central to CBA's utility theory and welfare economics roots[56,62], are at odds with many Indigenous conceptions of community well-being and communal property rights and obligations[64,65].

It is also important to recognize that the theoretical basis of traditional CBA requires substitutability between different types of costs and benefits. For example, it is assumed that an environmental or cultural loss can be exactly offset by other gains assessed as having the same value, such as protection of property or monetary compensation[56]. Many Indigenous values are not substitutable in this way, which makes it difficult, or potentially impossible, to use CBA to evaluate the costs and benefits of retreat on Indigenous groups and land[64–66]. **As with other non-market values, opinions differ on whether it is better to attempt to monetize Indigenous values so they are less easily ignored, or whether these values must be considered separately, such as through an MCDA, due to worldview incompatibility.** Assessment approaches to help address these issues include:

- non-compensatory forms of MCDA (i.e., those that do not aggregate scores under the same assumption of substitutability)
- setting minimum performance thresholds or standards for values where losses beyond a certain level cannot be compensated (e.g., using CBA to find the best option that preserves 75% of a wetland area or that does not impact a culturally important site)[55]
- deep engagement with the community to determine which values are important and how they should be considered in the decision-making process

Scope and Boundary Selection

Designing a CBA requires selecting geographic and political boundaries and identifying who has standing as an affected person[56,67]. These choices determine the scale at which costs and benefits are assessed, and which effects are interpreted as transfers or redistributions within the system, and therefore as net-neutral [56]. For example, a municipal-scale CBA may view post-retreat reductions in municipal property tax as a cost, while a regional- or provincial-scale assessment could see this as a net-zero change as the household's taxes are simply transferred to another community. Similarly, some land uses may continue elsewhere post-retreat (e.g., relocating a building, business, or farming operation to unused land), which could be a low- or zero-cost effect at a larger scale but may appear as a loss at a smaller scale[68].

It is very important to align the scope of a CBA with the context of the Managed Retreat decision being made, to consistently apply that scope throughout the assessment process, and to understand the scope of other assessments when attempting to compare results across studies. When there is no compelling reason to use a local level scope (e.g., municipal-scale decision-making by a local government), it is generally good practice to default to a large scale (e.g., provincial or federal) to fully capture all societal impacts[56,68].

Scenario and Baseline Design

When using CBA to assist in flood mitigation planning, the options being compared will be made up of various scenarios that describe different potential futures, primarily distinguished by the use of different, or different combinations of, flood risk reduction strategies. The proposed approaches are typically drawn from the four major categories of flood mitigation approaches: protect, accommodate, retreat, and avoid (e.g., relying solely on diking (protect), Managed Retreat from the highest risk areas combined with flood-proofing measures on lower risk buildings (retreat & accommodate)). Each scenario must have sufficient detail to be able to evaluate its costs and benefits, such as dike location, height, and construction requirements, which buildings are intended for retreat, and/or the types, effectiveness, and level of uptake of accommodation measures that may be implemented.

The design and choice of the scenarios under consideration is an important step, since options that are excluded from the assessment are automatically precluded from being selected, and analyzing unfeasible or unrealistic scenarios wastes resources and does not aid in community planning[67,69]. For example, **creative forms of Managed Retreat have been proposed that involve purchasing or rezoning at-risk properties now, and allowing for continued use** (e.g., rent-back or lease-back arrangements) until pre-determined trigger is reached, at which point the properties are vacated and demolished[5,36,70]. These alternatives can help reduce community opposition, fund property purchases through rental and leasing income, and provide timing flexibility in the face of uncertain rates of climate change[5,36,70]. Similarly, it can be beneficial to assess different possible scales of retreat, ranging from just the most at-risk properties to the full floodplain. **Failing to assess creative and varied designs like these may result in selecting a less desirable, higher-cost alternative**.

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Additionally, the selected scenarios are not compared to an unchanging version of the present, but to a prediction of a future where none of the alternatives are implemented, known as the baseline[56]. This step is necessary due to the potentially large changes that may occur over the lifespan of the project, which could have a significant impact on the assessment of costs and benefits (e.g., extensive development behind a dike over the next several decades could greatly increase the flood protection values of the dike, while also increasing the projected losses if a flood were to occur). However, uncertainties in future economic growth, technological innovation, cultural change, and the degree to which individuals take on adaptation independent of government programs (e.g., moving out of floodplains, installing flood-proofing at their own cost) make it challenging to set realistic baselines, adding further uncertainty to the analysis[67,71,72].

Good practices when designing mitigation and baseline scenarios include: providing opportunities for community engagement to discuss values and visions for the future; including a range of creative and varied mitigation scenarios; aligning the level of effort in designing mitigation and baseline scenarios with the magnitude of the decision being made; and, being transparent in the baseline assumptions being made (e.g., rates of economic growth, population change, technological advancement).

(Deep) Uncertainty

Disaster risk reduction and climate change adaptation involve many forms of uncertainties, including future changes in climate and social systems, the cost and effectiveness of adaptation measures, and attempts to measure the value of non-market impacts[73]. Additional uncertainty is introduced from downscaling climate change projections to local levels, particularly for extreme events and smaller-scale watersheds [74,75], as well as uncertainties from damage models that translate climate conditions (e.g., flood depths) into estimates of physical impacts from extreme events[45,76].

Some uncertainties can be addressed in CBAs through the use of 'expected values', which are a simple calculation of the probability of occurrence multiplied by the expected impact (e.g., a benefit with a value of $100 and a 25% chance of occurring has an expected value of $25). However, expected value calculations are difficult when faced with the combined uncertainties discussed above[73], and they break down entirely for 'deep uncertainties'[77], where probabilities cannot be assigned[78]. **Climate change adaptation faces many 'deep uncertainties' because future climate and cultural conditions depend on unknowable future societal choices (e.g., greenhouse gas emissions and mitigation), technological developments, and possibly extreme climate change feedbacks and effects**[26,48,78].

How much effort is put into analyzing uncertainty in a CBA should be commensurate with the scale of the decision and the resources available (i.e., more detailed analysis for more impactful decisions, less detailed analysis for smaller decisions). However, it is good practice for all CBAs to at least perform a sensitivity analysis of key uncertain values to examine how changes within a reasonable range could affect the outcome. Sensitivity analyses can also be used to identify which options perform well in a range of potential futures, or to determine where additional resources should be spent on studies to reduce uncertainty.

Proposed techniques to supplement or replace CBA to better handle deep uncertainties include mathematical approaches like Real Options Analysis (ROA) or Robust Decision Making (RDM), and adaptive management approaches like Dynamic Adaptive Policy Pathways. However, these approaches are more complex, require additional information that may not be easily available, and/or require ongoing monitoring and flexibility.

Time Horizons and Discount Rates

Most CBAs discount the future compared to today, which means that present day and near-future costs and benefits are valued more highly than ones in the distant future. This is done to account for opportunity costs and 'time preference'. Traditional discount rates, which tend to be higher and are often based on expected investment returns, can bias CBA outcomes against actions with high upfront costs but large long-term benefits, which includes many climate change adaptation strategies[61,7].

Time Preference

$100 today >
$100 in a few years

Many proposals have been made to address this issue, such as using low, declining, or even negative discount rates[8,45,67,79,] or using a zero discount rate for environmental and other non-market values[61]. Using these lower discount rates will give greater weight to costs and benefits that occur further in the future compared to the traditional, higher discount rates. In contrast, other economists argue that traditional discounting theory is sound, suggesting that adopting different discount rates for far future events introduces bias[80]. With no consensus on the most appropriate discounting method, analysts often use prescribed or typical discount rates for their location, and then perform sensitivity analyses to examine how different discount rates would change the outcome[45,47,67,81].

These issues are particularly important for Managed Retreat, where initial buyout costs can be high, but the flood damage reduction benefits accrue indefinitely. This is in contrast to dikes and seawalls which have a long but limited lifespan and therefore require costly reconstruction or transitioning to another strategy at the end of their functional life. In general, good practice for Managed Retreat CBAs involves using a relatively long time horizon and conducting a sensitivity analysis showing the impact of using different discount rates on the various options.


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Subjectivity and Comparisons

The potentially subjective and inconsistent choice of discount rates, values, valuation methods, time horizons, and other factors in CBAs makes it difficult to compare between and extrapolate results from other flood risk reduction studies[32]. While a standardized CBA process could help to overcome these challenges, such standardization might prevent the necessary context-specific aspects of CBA design, and could entrench poor practices (e.g., excluding particular non-market values)[70].

Where standard methods are not prescribed, it is important for decisions around assessment design to be transparent and clearly communicated to allow all readers to put the outcome into the proper perspective. Alternatively, when designing and setting out standards for others to use, these decisions gain even more weight and should be developed through careful consultation with affected parties and consideration of the various issues discussed in this report.

Non-Marginal Impacts, Equity, and Risk Aversion

Typical CBAs do not account for the larger relative impacts experienced by people with less resources, financial or otherwise (e.g., **a $1,000 loss will have a greater well-being impact on a low-income household than a wealthier one**), or when flood impacts are relatively large, regardless of wealth (e.g., complete building loss leading to homelessness will have more than two times the well-being impact of building damage equal to 50% its value). Scaling factors, known as equity and risk aversion weights, can be used to account for these types of effects where the impact is greater than the market cost would suggest due to differences in wealth/resources or where impacts are large and no longer considered 'marginal'.

These approaches are particularly useful when other programs are inadequate to address inequality and/or catastrophic loss (e.g., insurance, social supports, disaster recovery funding), or when retreat programs have explicit equity objectives. However, these methods add further complexity and uncertainty to the analysis and require substantial, local level information to implement.

If it is not feasible to use equity or risk aversion weights in a Managed Retreat CBA, but equity and the distribution of impacts is important to the decision-makers, then these factors may need to be considered elsewhere in the decision-making process, such as within an MCDA. Alternatively, constraints can be used that only select options that remain within a pre-determined equity or risk aversion thresholds (e.g., no expected deaths, maximum population exposed)[64].


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Optimism Bias and Over-reliance on CBA

CBAs have been shown to consistently underestimate costs, overestimate benefits, and place unfounded confidence in the accuracy and unbiased nature of these estimates. This optimism bias results in overestimating benefit-cost ratios by an average of 50-200% depending on the investment type[82]. Despite this, and the other issues discussed above, there is a common over reliance on CBAs, rather than using CBA studies as one piece in a larger decision-making process[77].

Overcoming these challenges requires careful consideration of all steps in the design and execution of the CBA, as well as the decision-making process as a whole. Pre-determining how the CBA will be carried out and used, in addition to transparency and community engagement throughout, can help to limit bias and reduce the temptation to simply select the CBA's preferred option.

3.2 Multi-criteria Decision Analysis

3.2.1 Methodology

Multi-criteria Decision Analysis (MCDA) is another common decision support tool used to assess and rank alternatives, but **unlike CBA, MCDA can consider monetized, non-monetized, qualitative, and quantitative measures at the same time[83]. MCDA exists in many different forms (the MCDA Methods Selection Software website helps to select from more than 200 variations)**, but the general process shared by most forms includes:

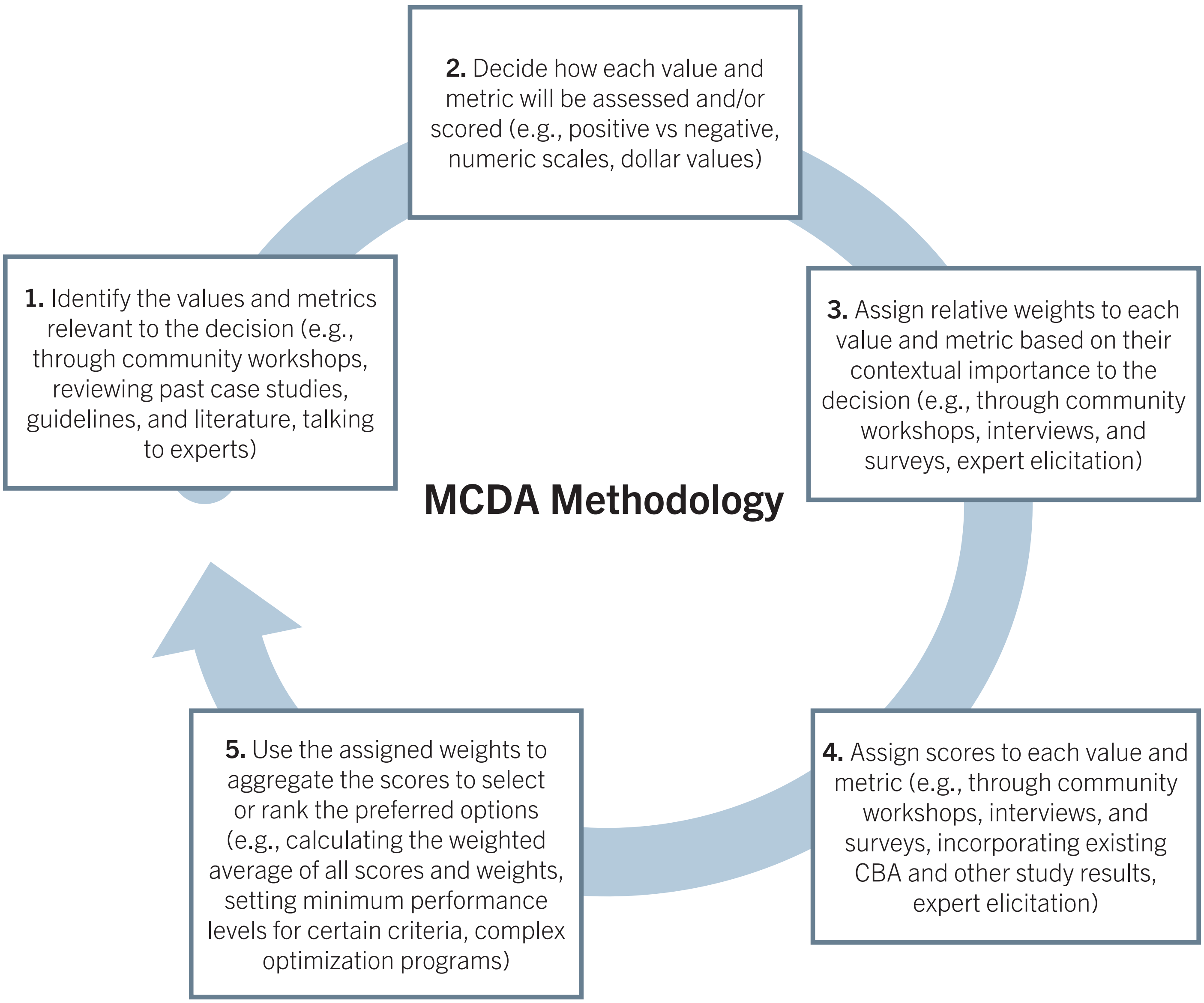

Figure 3: Multi-Criteria Decision Analysis (MCDA) Methodology. Cross, 2024

As compared to CBA, MCDA is better suited to exploring alternatives and facilitating dialogue, and the overall process, relationship building, and learning that goes on through MCDA is often more important than the final outcome. The MCDA process often becomes iterative, where new values, priorities, impacts, interested parties, and/or knowledge gaps are identified, and earlier steps then need to be repeated or expanded.

The MCDA process can also produce various graphs, figures, and data that can be used for broader community planning communication efforts. For example, sensitivity analyses can be carried out to reveal how much scores or weights would need to change to reach a different preferred option, which can help focus discussions on which options could realistically be selected and on the key factors affecting the decision. Helpful visualizations can also include color coding the scores across the various categories to help understand trade-offs between alternatives (e.g., Figure 5), or using pie charts to show category weights. For more complex decision-making, there are also more mathematical approaches, such as plotting the standard deviation of each participant's ranking of each alternative against the mean ranks to help visualize where there is strong agreement and where further discussion is needed[55].

MSPhotographic/iStock

3.2.2 Benefits, Limitations, and Challenges of Using MCDA

Benefits of using MCDA include:	**Limitations and Challenges of using MCDA include:**
• Can make the decision process more comprehensive, transparent, explicit, rational, and efficient • Promotes the role of participants in the decision-making process and facilitates compromise and group decisions • Provides a platform for participants to communicate and discuss values and preferences • Can be used in combination with other assessments and tools, such as environmental and social impact studies and CBAs • Can be more suitable than CBA where major impacts are intangible or non-monetizable • Does not assume that all participants have the same trade-offs, values, and relative priorities • Exists in many forms and levels of complexity (e.g., from simply assessing whether each indicator is positive, neutral, or negative for each alternative[84], to highly complex computer models that optimize across multiple objectives[64,85]) • Helps to identify areas of discussion, negotiation, and need for further investigation	• Typically less rigorous than CBA regarding uncertainty, discounting, and quantifiable impacts, and many measures are subjective. By producing a final numerical score, it can also lead to false assumptions on the level of precision and accuracy in the assessment • Can be very time consuming and expensive to implement, especially when best practices are followed to include widespread participation at all stages of design, implementation, and decision-making • Care must be taken to avoid double counting impacts when determining and scoring the list of factors/indicators • Requires large time commitment from participants to realize the full benefits of MCDA • The process and resulting decision can still be biased by who is included, who has the capacity to fully participate, particular participants dominating the discussion, omission of important values, and expression of pre-existing biases through scoring and weighting • Decisions are often still based on utilitarian thinking and assumptions similar to CBA (e.g., assuming substitutability and allowing for benefits in one category to compensate for a loss in any other category)

3.2.3 Multiple Accounts Analysis (MAA) as a Common Form of MCDA

Multiple Accounts Analysis (MAA) is a common form of MCDA used in British Columbia for natural resource management and public land use planning that uses four 'Accounts' to divide the values under consideration: Technical, Economic, Environmental, and Socio-Economic. Each Account has a series of Sub-accounts that subdivide the Accounts into more specific impacts, and each Sub-account may have multiple indicators that specify how those impacts will be evaluated, which can range from quantitative to qualitative. For example, under the Environmental Account, the sub-account of Water Quality may include indicators like pH, dissolved oxygen, and total dissolved solids. The relevant sub-accounts and indicators will be project-specific and should be identified through broad engagement of all interested parties.

Once all of the sub-accounts and indicators are identified, they are recorded and scored in a large table, or series of tables, known as the 'Ledger' (see Figures 4 and 5). The most common scoring system for MAA is to use a 9 point scale where the best performing alternative for that indicator receives a 9 and the other alternatives are scored on their relative performance (e.g., an alternative that is considered to be half as good for that indicator would receive a 5).

Each indicator, sub-account, and account is also assigned a weight on a 5 point scale, with the most important receiving a 5 and all others scored based on their relative importance (e.g., a sub-account with a weight of 4 would be twice as importance as a sub-account with a weight of 2). Assigning these scores and weights should be a collaborative process involving a wide range of participants (e.g., experts, community members, decision-makers, other interested parties). These weights are used to calculate weighted and normalized scores for each sub-account and account, as shown in Figures 4 and 5.

Indicator Weight W_i

Alternative A

Account	Account Weight	Sub-Account	Sub-Account Weight	Indicator	Indicator Weight	Alt A	Alt B	Alt C
Technical	3	Groundwater Capture System	5	Efficiency	5	5	3	9
				Maintenance Requirements	1	9	7	7
				Operating Requirements	2	9	3	1
Sub-Account Score						6.50	3.50	6.75

Sub-Account Score = SUM (W_i x $S_{i,A}$)/SUM(W_i)

Scalar Value $S_{i,A}$

Figure 4: MAA Sub-account ledger example showing the breakdown of Accounts into Sub-accounts and Indicators, and the process of scoring and weighting each indicator to calculate the Sub-account score for each alternative. Robertson and Shaw, 2006[56].

Accounts	Account Weights	ALT A	ALT B	ALT C	ALT D	ALT E
Scoring with all Accounts weighted by relative importance.						
Technical	3	5.68	7.28	7.69	8.17	7.58
Project Economics	2	7.88	7.32	6.54	5.13	3.29
Environmental	5	5.96	7.31	7.21	7.64	7.69
Socio-economics	3	4.45	5.81	5.69	6.83	7.30
MAA Score		5.84	6.96	6.87	7.19	6.90
Re-scoring with Project Economics weighted a '0'						
Technical	3	5.68	7.28	7.69	8.17	7.58
Project Economics	0					
Environmental	5	5.96	7.31	7.21	7.64	7.69
Socio-economics	3	4.45	5.81	5.69	6.83	7.30
MAA Score (Excluding Costs)		5.47	6.89	6.93	7.56	7.55

Figure 5: MAA Accounts ledger showing the weighted summation of sub-account scores for each alternative. This example also demonstrates the ability to re-calculate the scores and compare the change in rankings using different weights – in this case by assigning a weight of 0 to Economics in the lower portion of the ledger . Robertson and Shaw, 2006[56].

As shown in Figure 5, it is also possible to test different prioritizations by recalculating the scores with different weights. In this case, the alternative scores are recalculated with the Economics account weight set to zero to explore how the rankings would change if project economics were not a factor. In this example the preferred option (Alternative D) does not change, but Alternative E moves to be almost as high scoring as Alternative D. These types of experiments can help direct future discussions or studies, such as raising questions about whether selecting the otherwise best performing alternative is worth the additional financial costs, or testing the weights proposed by different community groups to see how the resulting rankings are similar or different.

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MAA can be a good choice of MCDA methodology due to its history of use and familiarity among some groups. The well-established Accounts process helps to guide participants in identifying relevant values and indicators, and the relatively simple scoring and weighting system can be understood quickly and provides transparent results compared to some of the more complex MCDA models available.

However, there are some factors that mean that MAA it is not always the best choice of MCDA or alternative decision-making processes. First, the simple weighted sum scoring system is based on the same utilitarian thinking as CBA and makes the same assumption of substitutability between different indicators, sub-accounts, and accounts, because a high score in one area can make up for a low score in any other. Second, the weighted sum scoring system can imply a false sense of precision despite using a fairly coarse scale for the scores and weights. Interpreting the results takes more time and care than simply comparing the final scores. Third, it can be difficult to avoid overlap and 'double-counting' of impacts given the potentially large number of indicators and sub-accounts that may be generated in the initial community engagement stages. The process of deciding on a final list of indicators and sub- accounts, as well as the scoring and weighting processes, can be very time consuming and difficult to reach consensus on when working with diverse communities and for projects with contested goals and objectives, such as Managed Retreat.

4

Case Studies and Examples of CBA and MCDA for Managed Retreat

Compared to structural flood protection, there are relatively few relevant examples of Managed Retreat to examine because it is fairly new as a mainstream approach to flood risk reduction and climate change adaptation, and there are even fewer where CBA or MCDA were used as part of the decision-making process. However, there are examples from British Columbia and other similar jurisdictions that provide useful examples to build upon, as well as lessons for improving the assessment and decision-making processes.

Please note that this section focuses on the **use of CBA and MCDA for the assessment of proposed retreat programs**, rather than providing examples of Managed Retreat programs in general. For more information and lessons learned from how Managed Retreat has been implemented in other jurisdictions, other useful case studies include Gatineau (Quebec), High River (Alberta), New York (New York, USA), New Orleans and Isle de Jean Charles (Louisiana, USA), Christchurch (New Zealand), and Newtok, (Alaska, USA), however, these examples are not explored here as no decision support assessments have been published.

It should also be noted that the example assessments described below do not necessarily reflect final project designs or decision-making processes, but instead represent snapshots in time based on when these assessments were completed within the project lifecycle. For example, Merritt B.C.'s Land Acquisition Program (see Section 4.2) was still in the proposal stage at the time of writing, and the exact nature of the project and the assessments used to aid in decision-making may change in the future. Similarly, the Sumas Prairie assessment (see Section 4.3) is largely hypothetical at this point in time and any future implementation may differ substantially from what is currently proposed. The following section outlines key aspects of five examples (1. Grand Forks, B.C.; 2. Merritt, B.C.; 3. Sumas Prairie, B.C.; 4. Calgary, AB; and, 5. FEMA's US approach), plus a brief review of related academic research examples. A table containing the parameters and other details of how CBA and/or MCDA was used in each case (e.g., scenarios considered, costs and benefits assessed, assessment parameters like discount rate and time horizon) can also found in Appendix 3.

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4.1 Grand Forks, British Columbia

Following an estimated 1 in 200-year flood in May 2018 that damaged more than 400 homes and left more than 50 homes damaged beyond repair, the Grand Forks City Council decided to pursue a widespread flood recovery and mitigation program that included the buyout of approximately 130 properties in high-risk areas in addition to numerous flood protection measures (e.g., new dike construction, dike repair and raising, installing ponds, culverts, a pump station, and erosion protection). In support of an application for Disaster Mitigation and Adaptation Fund (DMAF) funding to complement the flood recovery program, Grand Forks hired Nor-Ex Engineering to produce a CBA/Return of Investment (ROI) report on the proposed buyout and flood mitigation works, which had a projected ROI of 3.4:1 for the project as a whole.

The only formal assessment Grand Forks completed for their flood mitigation plan was the CBA/ROI in support of DMAF funding, rather than conducting a similar analysis to decide between different mitigation options. This is likely due to the need for rapid resolution of the post-flood buyout and flood recovery program and the need to meet the DMAF application deadline.

DMAF ROI calculations are a very simple variation of CBA, only accounting for the direct monetary costs and benefits of the works associated with the funding request, using an implicit discount rate of 0%, and only assessing the single preferred option as a whole (i.e., no comparisons with alternative strategies, no assessment of buyouts independently from the structural measures).

* Additional time for planning and decision-making (particularly if performed pre-flood), could have helped to identify a wider range of mitigation alternatives, increased decision-making transparency, and allowed for more community engagement and communication, which may have reduced community opposition and implementation challenges.

* The funding available to Grand Forks was initially approved based on current (i.e., post-flood) fair market property values, which placed financial restrictions on the level of compensation the City could offer to property owners. Eventually, additional in-kind and top-up funding was secured, leading to buyouts being offered at closer to pre-flood values. While the program had a high voluntary participation rate, costly expropriation processes were required for some properties. The compensation offered, combined with rising housing prices, prevented some households from finding equivalent housing within the community or led to foreclosure and bankruptcy. The largest financial burdens may have been shouldered by the owners who experienced the greatest loss during the flood.

* The CBA/ROI report makes the limited scope clear, but readers must be very careful not to assume the results can be applied to other decision-making contexts (e.g., other communities facing different social and environmental conditions, or situations where the proposed plan is designed to be beneficial to society at large rather than more narrowly on the relocated households).

* During the flood recovery process, Grand Forks used some of the acquired properties as temporary rentals in an effort to increase the limited housing supply. While this helped to offset some of the costs of the program, the decision to use the purchased houses in this way was made at a later date, was not communicated to buyout participants beforehand, and led to community confusion and dissatisfaction. While this is an example of how creative approaches can help to fund buyouts while maintaining the housing supply, it also demonstrates the importance of transparency, communication, and the benefit of early planning when possible.

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4.2 Merritt, British Columbia

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Merritt experienced severe flooding in November 2021 as part of the widespread atmospheric river event that affected much of southwest British Columbia. Following this flooding, the City of Merritt undertook comprehensive flood mitigation planning, including the selection and assessment of a series of options using MCDA and community workshops. The options considered included: Option 1 – Do nothing/status quo; Option 2 – Full floodplain retreat; Option 3 – Waterside diking; and, Options 4A/4B/4C – Different combinations of waterside and setback diking. It is worthwhile noting that, in addition to 'full floodplain retreat', limited retreat/buyouts would likely also be needed in order to implement the diking options. The results of the MCDA and the community workshops led to a modified version of the combination diking scenarios ("Option 5") being selected as the preferred option, and the City hired Nichols Applied Management Inc. (NAMI) to produce a CBA/ROI report in support of a DMAF funding application for the implementation of Option 5, which had a projected ROI of 7.1:1.

- Managed Retreat as a primary flood risk reduction strategy was only included in Merritt's initial planning as a single Full Floodplain retreat scenario, which included a large proportion of the town's core.

- As with Grand Forks above, the Merritt DMAF ROI calculation is very limited in scope and applicability to other decision-making contexts. Other limitations include a baseline scenario that assumes no change in the number or type of dwellings in the affected area over the next 100 years, and an assumption that environmental and cultural heritage impacts can be mitigated for minimal cost and therefore will not affect the ROI.

- The report prepared by NAMI made some attempts to broaden its use, including a sensitivity analysis using a range of discount rates and a break-even analysis, and includes an attempt to measure some non-structural impacts such as public health and quality of life impacts, school closures, and business disruptions. It also discussed environmental, heritage, and cultural impacts but did not attempt to monetize these effects.

- As with the Grand Forks assessment, this report is also very clear about its intended scope, objectives, and limitations.

As part of the implementation of the chosen flood mitigation plan, the City of Merritt has proposed a Coldwater River Land Acquisition Program (C-LAP) to acquire properties that are needed to complete the planned diking upgrades and new dike construction. Merritt's approach to this program provides several useful examples of the types of issues and considerations that arise when property acquisition is part of a structural hazard mitigation plan, including:

- Although C-LAP's primary purpose is to allow for the construction of flood protection works, rather than simply the removal of people and buildings from hazard areas, it shares virtually all of the characteristics particular to Managed Retreat, including the provision of flood protection benefits to the wider community. This shows the flexibility of the term Managed Retreat and demonstrates that the approaches described in this report can also apply to a broader range of initiatives that share the same features and challenges.

- **A key feature of C-LAP is the use of an equity valuation model that aims to provide sufficient compensation for participants to relocate to an equivalent home within the community under the current real estate market.** This valuation model is based on pre-flood values plus additional compensation to account for factors like market increases since the pre-flood valuations, relocation expenses, and consideration for other potential financial damages resulting from the buyout process.

- C-LAP's objectives explicitly reference the desire to reach a 100% voluntary acceptance rate and to minimize post-buyout social costs and the erosion of community resilience. The proposed equity valuation model is a good example of how careful choices made in the design and analysis of retreat programs can be aligned with program goals and objectives to increase the likelihood of positive community outcomes.

- **The City of Merritt's budgetary analysis predicted that the costs of the proposed equity valuation model would be only marginally higher than using a post-flood model. Under the post-flood valuation model, the savings from the lower purchase costs are expected to be largely erased by legal fees related to expropriation proceedings.** Proceeding with expropriation would likely also be accompanied by additional social, health, time, and financial costs for the households involved. This counterintuitive finding points to the importance of attempting to account for all relevant costs and benefits, such as legal and administrative costs, social support costs for affected households, and community resilience benefits.

4.3 Sumas Prairie, British Columbia

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Extensive flood recovery work is still ongoing in many communities following the November 2021 flooding. On the Sumas Prairie, including the area that was formerly Semá:th Xo:tsa (Sumas Lake), efforts continue in support of advancing flood risk reduction while restoring important habitat and ecosystem functions. Alongside this process, a group of researchers and non-governmental organizations examined the cost of an alternative solution of reclaiming and revitalizing Semá:th Xo:tsa via Managed Retreat. This group included the Lower Fraser Fisheries Alliance, West Coast Environmental Law, Raincoast Conservation Foundation, and University of British Columbia faculty. The results of this work were published in the academic journal Frontiers in Conservation Science in June 2024[86].

Rather than attempting to produce a comprehensive assessment of all potential impacts of managed retreat from Semá:th Xo:tsa, the authors performed a simple calculation of summing the pre-flood assessed values of all properties within the historic lakebed boundary, which totaled approximately $956 million. This total was then compared to the estimated costs of four flood recovery option proposed by the City of Abbotsford, which ranged from approximately $200 million to $2.4 billion, to illustrate “how the option of reclaiming and revitalizing the lake is within the realm of economic costs associated with maintaining the status quo and presents a missing narrative.”.

The authors acknowledge that the estimated price of managed retreat omits additional, potentially large costs such as planning, communication, cleanup, removal, and/or relocation of infrastructure, decontamination, the construction of dike infrastructure depending on the scale of retreat, and the loss of highly productive agricultural land. However, the simplified assessment also omits the benefits of reduced future flood damage, improved stewardship of the environment and biodiversity, and the restoration of Indigenous food systems, improved social cohesion, and nation building. All additional impacts would need to be assessed in greater detail before the CBA could be used for decision-support, rather than as a rough estimate of the scale of managed retreat.

4.4 Calgary, Alberta

Following two days of intense rainfall, the Alberta floods of June 2013 resulted in the displacement of over 100,000 people in multiple communities, and more than $5 billion in property damage, spurring the desire for extensive flood risk reduction to prevent a similar event in the future. Given the high profile of these events and the large costs associated with the proposed mitigation works, the City of Calgary did extensive studies and planning in support of their flood mitigation plan. This planning included an MCDA, referred to as a "Triple Bottom Line Analysis", to select the preferred options from a list of potential projects, and then a CBA of two specific projects chosen as potential preferred options.

The 13 scenarios considered in the MCDA were largely different combinations of reservoir construction and structural protection, but also included a buyout of all residential properties within the 1 in 200 year floodplain (Scenario 6). Figure 6 shows the MCDA summary for Scenario 6, including the criteria used, scoring system, and basic cost/benefit assessment that was included in the MCDA scoring.

Description & Discussion

This option considers purchase of all residential properties within the approximate 1:200 year floodway (defined by a 1 m depth) at 2016 assessed values. The majority of properties within the approximate 1:200 floodway are residential. Non-residential properties in the floodway are varied and include the Calgary Stampede, the zoo, the Holy Cross Hospital site, and several schools. Because most non-residential properties would require individual assessment for buyout applicability, only residential properties were included in this analysis.

Within the 1:200 year floodway, there are approximately 980 residential buildings. The total assessed property value amounts to over $1.8 billion. Removal of all the damages associated with these buildings reduces the AAD by $27.2 million.

This option has a negative benefit/cost aspect with a ratio of 0.47. It achieves the lowest average annual benefits by not protecting anything beyond the floodway. In addition, no costs have been determined for restoration or rehabilitation of the land acquired, which could be significant.

Buyouts can be very disruptive to established communities, creating isolated and discontinuous pockets of housing. This can also make service provision less efficient.

Benefit/Cost Analysis

Development Cost	$1,818,000,000
O&M	$0
PV Benefits (average annual damages)	$853,170,000
PV Costs (development & operating total cost)	$1,818,000,000
Benefit / Cost Ratio	0.47
Net Present Value	-$964,830,000

Triple Bottom Line Analysis

GOAL	CRITERIA	SCORE	RANK
SOCIAL	Complete communities	-10	8
	Equitable protection	-9	10
	Vulnerable populations	-1	12
	River aesthetics	12	1
	Recreation access	6	4
	Emergency access	-2	10
	Risk transparency	1	10
ENVIRONMENTAL	Water security	0	9
	Riparian health and ecosystem functions	4	1
	Water quality and contamination prevention	0	3
IMPLEMENTATION	Timeliness of Implementation	-4	5
	Adaptability/Flexibility	9	3
	Jurisdictional control	6	4
	Regulatory complexity	-2	5
ECONOMIC	Economic Environment	-3	11
	Economic Efficiency	-18	12
	Damages Averted	-15	11
	Total Cost	-8	8
	TOTAL SCORE	-34	9

Figure 6: MCDA ("Triple Bottom Line Assessment") results for floodplain buyouts from Calgary Flood Mitigation Plan.

Along with a similar summary sheet for each scenario, the report includes a summary table showing the comparison and final scores and ranks of the 13 different scenarios (Figure 7). This summary table also demonstrates the use of color coding to make comparisons more intuitive, as well as a column for Highest Ranked Scenario by Criteria, which is an example of how MCDA can be used to generate discussion and consider how decisions would be made given different criteria weights.

Goal	Criteria	Objective To what extent does the scenario help achive the following objectives, **compared to the baseline existing condition?**	Scenario Rating (-6 to +6)												Weight (1-6)	Highest Ranked Scenario by Criteria
			0a Non-structural	1 SR1	1a SR1 + DT barrier	2 SR1 + Bow Res	3 Bow Res + Elbow barriers	3a 3 w/ GW	4 SR1 + Bow barriers	4a 4 w/ GW	5 Barriers on Bow+ Elbow	5a 5 w/ GW	6 Flood-way buyouts	7 SR1, Bow Res, Select barriers		
	Complete communities	**Maintains community fabric** *Preserves existing communities, homes and heritage. Maintains opportunities for revitalisation/densification (eg. East Village). Amenities and transportation choices are not negatively impacted.*	-1	3	4	6	-4	-4	-5	-5	-6	-6	-5	5	2	2
	Equitable protection	**Provides equitable protection from flooding** *across communities, the city and does not negatively impact upstream or downstream*	1	-4	-5	3	-2	-2	2	2	5	5	-3	4	3	5
	Vulnerable populations	**Protects vulnerable populations** *Risk-sensitive development, protection of Calgarians who because of age, disability or other circumstances are at greater risk.*	0	3	4	5	2	2	2	2	1	1	-1	5	1	2
Social	River aesthetics	**Maintains community and river aesthetics** *River views from private and public property, natural-looking river*	-1	5	1	5	-5	-5	-4	-4	-6	-6	6	4	2	6
	Recreation access	**Maintains or enhances accessibility and recreation opportunities** *Protects/provides access to the river, riparian areas, natural areas, and parks.*	1	5	-1	5	-4	-4	-5	-5	-6	-6	3	4	2	1
	Emergency access	**Protects connectivity and ease of access and departure during flooding or other emergencies/disasters** *Does not negatively impact emergency response, reduces residential and non-residential loss of life*	2	3	2	3	-1	-1	-1	-1	-2	-2	-2	3	1	1
	Risk transparency	**Increased transparency/visibility of risk** *For property owners/prospective buyers regarding flooding risk*	2	1	2	1	3	3	3	3	4	4	1	3	1	5
		TOTAL Community Well-Being score	**5**	**21**	**1**	**50**	**-28**	**-28**	**-18**	**-18**	**-18**	**-18**	**-3**	**49**	12	2
	Water security	**Protects/provides water supply security** *Promotes efficient, sustainable water management so that the region's water supply meets the current and future needs of a growing city and region of users (municipalities and irrigation districts).*	0	1	1	6	6	6	1	1	0	0	0	6	6	2
Environmental	Riparian health and ecosystem functions	**Protects riparian health and species habitat and allows natural ecosystem functions** *Protects/enhances riparian areas and health of aquatic and terrestrial species. Lets the floodplan flood, provides room for the river, allows the river to flood*	1	-1	-1	-1	-4	-4	-4	-4	-6	-6	1	-2	4	0a
	Water quality and contamination prevention	**Protects river water quality and prevents contamination of air, land, and water** *Does not have a short or long term detrimental impact on water quality and prevents contamination from spills, stormwater and groundwater flooding, transportation of goods, construction of scenario.*	-1	-2	-2	0	2	2	-2	-2	0	0	0	0	2	3
		TOTAL Environmental score	**2**	**-2**	**-2**	**32**	**24**	**24**	**-14**	**-14**	**-24**	**-24**	**4**	**28**	12	2
	Timeliness of Implementation	**Contributes to orderly implementation of investments.** - *Timeliness and ease of implementation. How quickly can it be implemented and does it complement future measures?*	-2	5	4	-3	-5	-5	1	1	-4	-4	-1	-2	4	1
Implementation	Adaptability/Flexibility	**Contributes to flexibility of implementation.** How ***adaptable*** *the solution is - ease of future adaptability and flexibility (can it be raised/improved, can it address climate change issues?)*	1	2	2	4	3	3	2	2	-1	-1	3	5	3	7
	Jurisdictional control	***How easy it is for the City to implement.*** *Jurisdictional ability of The City to implement; financial ability for The City to implement; dependent on other jurisdictions to commit to/implement/fund.*	4	0	1	-3	-2	-2	1	1	3	3	2	-2	3	0a
	Regulatory complexity	**Complexity of regulating land use and development with respect to different structural mitigation measures.** *(City: bylaws; At the Provincial and Federal levels: environmental and land/building regulations, mapping, funding, disaster relief programs)*	-3	-2	-2	3	-3	-3	-3	-3	2	2	-1	4	2	7
		TOTAL Implementation score	**1**	**22**	**21**	**-3**	**-23**	**-23**	**7**	**7**	**-6**	**-6**	**9**	**9**	12	1
	Economic Environment	**Indirect Protection of Calgary's economic engine (attracts businesses, business continuity)** *Protects the downtown and business continuity. Protects critical infrastructure and essential services, transportation corridors.*	-1	3	5	5	2	2	2	2	2	2	-1	5	3	1a
Economic	Economic Efficiency	*Benefit/Cost Ratio*	6	5	0	-2	-4	-4	2	0	-1	-2	-6	-3	3	0a
	Damages Averted	*Total Benefits*	-6	3	4	6	3	5	5	7	3	6	-5	6	3	4a
	Total Cost	*Present Value of deveopment and operating costs*	6	5	2	-4	-5	-6	2	1	1	-2	-3	-4	3	0a
		TOTAL Economin score	**15**	**49.19**	**33.4**	**13.73**	**-9.231**	**-8.53**	**35.9**	**29.13**	**14.69**	**12.42**	**-44.1**	**12.94**	12	1
		Total Score	23	90.2	53.4	92.7	-36.2	-35.5	10.9	4.13	-33.3	-35.6	-34.1	98.94		**7**
		Rank	5	3	4	2	12	10	6	7	8	11	9	1		

Figure 7: MCDA ("Triple Bottom Line Assessment") scoring sheet from Calgary Flood Mitigation Plan.


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* The CBA which followed the MCDA compared the financial impacts of the McLean Creek flood storage project ("MC1") and Springbank flood storage project ("SR1") in much greater detail than in the MCDA.

* Although the CBA did not include a buyout or retreat option, it did provide a good example of how to carry out a very thorough CBA that includes multiple methods for estimating the cost of land acquisition, including the challenges of assessing property types that have little market data and comparing market values to anticipated revenues for farmland.

* The CBA focused on market costs and only provided a list of (but does not attempt to monetize) the predicted non-market and intangible effects of the projects. This is a good example of how an MCDA and a CBA can provide complementary information to be used in the final decision-making process.

* While buyouts were part of the recovery programs of other 2013 flood-affected communities, such as in the Town of High River, no CBA or MCDA is available for those programs. However, the High River buyout example is notable for its initially low uptake despite offering pre-flood valuations, and for criticisms levied against municipal officials for using outdated and inaccurate floodplain maps to determine buyout eligibility. This example demonstrates the uncertainty of success when trying to measure the costs and benefits of Managed Retreat programs, the value of careful design for retreat planning and assessment (e.g., comparing the costs and benefits of retreat under the outdated versus updated floodplain maps), and the observation that buyout uptake can be dependent on more than just monetary compensation levels, showing the importance of non- market values and impacts.

4.5 FEMA: Federal Emergency Management Agency Hazard Mitigation Assistance Programs

Hazard risk reduction programs applying for FEMA Hazard Mitigation Assistance (HMA), such as a municipal- or state-led buyout program, are required to demonstrate cost effectiveness, which is usually accomplished using FEMA's benefit-cost analysis (BCA) toolkit. The toolkit is an Excel-based tool that is designed to reduce the administrative burden on applicants by providing standard values, valuations, and methodologies in a relatively simple to use format. As the main source of funding for hazard reduction buyouts in the United States, this standardized methodology therefore heavily influences risk reduction planning and decision-making across the country.

FEMA | Benefit-Cost Calculator v6.0.0

The details of FEMA's BCA methods are beyond the scope of this report, but there are several points which are relevant as a comparison to the BC and Alberta Managed Retreat cases.

- FEMA's arm's length approach to hazard risk reduction, providing funding for locally designed projects, allows for local context to more easily be built into the risk reduction strategies. However, **the requirement to demonstrate cost-effectiveness through a standardized assessment methodology can limit what is eligible for that funding, and reduce the contextualization needed to account for community uniqueness.**

- FEMA considers a building to be 'Substantially Damaged' when the total cost of repairs is 50% or more of the building's market value before the disaster. Owners who decide to repair a substantially damaged building are required to be brought into compliance with local floodplain management regulations (e.g., raising the structure to current flood construction levels, or adding flood proofing elements). As these kinds of upgrades can be beyond the financial reach of some homeowners, and lower value properties are more likely to reach the 50% threshold during a flood event, this can lead to disproportionate use of buyout programs in lower income neighborhoods, which raises equity concerns.

- In an effort to further simplify the cost-effectiveness requirement, FEMA has instituted a property value threshold below which all properties in identified Repetitive Loss (RL) and Severe Repetitive Loss (SRL) areas are assumed to be cost-effective for a buyout. As of September 2021, this threshold was set at $323,000. As with the two points above, while this approach reduces the administrative burden on local governments, it preferentially targets lower value neighborhoods for buyouts and is likely to skew which risk reduction options are considered due to the guaranteed HMA funding.

4.6 Academic Literature

The body of literature on CBA and MCDA of Managed Retreat is relatively small, but does provide several useful examples demonstrating different approaches to value selection and evaluation, proof of concept studies using novel tools and combinations of approaches, and alternative purchase and funding schemes. Details of these studies, such as the context, values considered, assessment parameters, and MCDA methods are detailed in Appendix 4, while a summary of key lessons that can be applied to BC Managed Retreat assessments is included below.

Brent Doberstein, Living With Water

Value Selection and Monetization Can Significantly Impact Assessment Outcomes

While each Managed Retreat assessment will require different values and approaches to measuring them, previous studies can help to identify values that might otherwise be missed or suggest ways of measuring difficult to assess values.

Across the different studies, the values considered and those that are monetized are quite different, which can have a large impact on the assessment outcome. **Monetized construction and implementation costs, and estimates of reduced Average Annual Damage, are the most common values considered**, but this is not universal. For example, one MCDA excluded cost entirely, which was noted as being useful for increasing the focus on typically undervalued considerations, but this led to the assumption that protection options would always be 100% effective, leading to a bias against non-protection options[43]. Similarly, one CBA study did not monetize any benefits, whether related to flood risk reduction or otherwise, making the protect, accommodate, and retreat options considered all appear equally as effective[87], which is unlikely to be the case.

Attempts to include a broader range of impacts also varies widely between studies. Most CBA studies at least make an effort to list potential non-market impacts, which could be an effective strategy depending on how the CBA fits into the wider decision-making process, while others use a range of monetization approaches. Some examples include valuing the recreation benefits of wider beaches[88], using increased psychotropic drug use post-flood as a proxy for psychological distress[70], and estimating the replacement cost of impacted ecosystems as an alternative to ecosystem services methods[88].

It is important to note that these challenges are not unique to CBA and also apply to MCDA. Most of the MCDA studies include a limited number of factors to make scoring and analysis easier and the authors acknowledge that many factors are still ignored in these assessments[43,84].

Explore Creative Use of Alternative Purchase and Ownership Schemes

Two of the academic studies reviewed included assessments of alternative purchase and ownership schemes, such as buy-and-rentback[70,88]. For properties that are expected to experience unacceptable flood risk in the future, typically due to climate change, these programs work by purchasing the properties well in advance and leasing the property back to the residents until a pre-determined retreat trigger is reached.

This approach can help support pro-active retreat by:

- reducing financial costs/providing a revenue source until retreat is implemented
- spreading out the initial capital costs if properties are purchased as they are put on the market rather than as a single block
- giving time for residents and communities to accept the change
- shifting financial risk from property owners to the government
- increasing communication and transparency

However, these types of programs do require additional planning and transaction fees and need to be implemented far enough in advance for the rent to cover a substantial portion of the total costs, and setting the retreat triggers can be difficult given the intermittent and uncertain nature of extreme weather events and climate change.

Alternative Tools and Combinations of Tools Can Be Effective in the Right Context

Academic studies often present useful demonstrations of new or non-standard approaches, or combinations of approaches, along with thorough discussions of their advantages, disadvantages, and other considerations. Lawrence et al. (2019) and Ramm et al. (2018) are two prime examples of this, each assessing simplified Managed Retreat case studies by combining alternatives to CBA (Real Options Analysis [ROA] with MCDA and Robust Decision Making [RDM], respectively) with a form of adaptive management and planning known as Dynamic Adaptive Policy Pathways (DAPP). DAPP or 'a pathways approach' is a planning method that compares different ways that alternative actions can be sequenced over time and the conditions (or 'tipping points') that would trigger a switch from one alternative to another when it is no longer effective (see Figure 8).

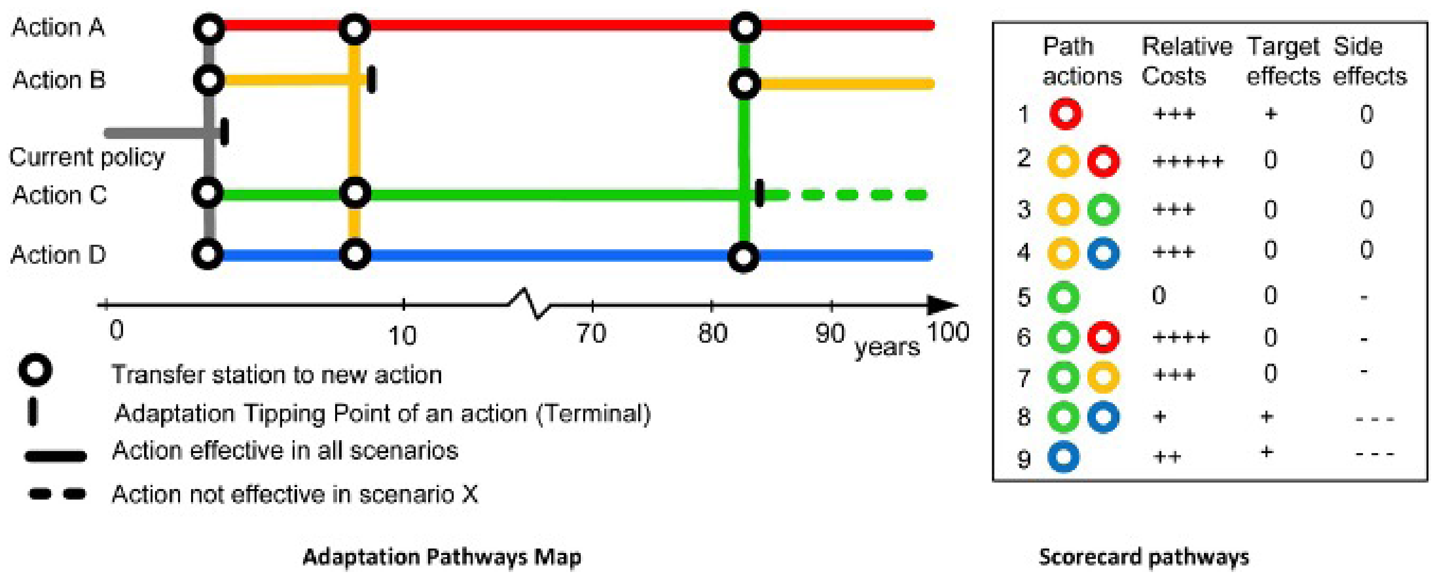

Figure 8: An Adaptation Pathways map example showing how different sequences of actions can be visualized and the relative costs and benefits compared. From Haasnoot (2013) [89].

Both studies provide detailed discussions of strengths and limitations of these approaches, but key lessons for Managed Retreat decision-making in BC include:

- **Pathways Approach: Assessing pathways that combine different flood risk reduction strategies over time, rather than framing the decision around the choice of a single strategy, helps to identify limitations, tipping points, time frames for important decisions, and key uncertainties.** For example, in Figure 8, Action C may appear attractive due to its low initial cost, but it may become ineffective at a later date and require a more costly transition to Action A, B, or D. Comparing these three scenarios to selecting either Action A or B, which remain effective indefinitely, but have higher initial costs, provides a more comprehensive view of the long-term options available.

- **Combining Approaches:** Combining a pathways approach with assessment techniques that more effectively consider uncertainty and the value of delaying action when appropriate (e.g., ROA, RDM) can help to identify better sequencing and timing of risk reduction strategies.

Resource Intensive Methods: Both ROA and RDM are data intensive, and require substantial knowledge, resources, and time to implement. The benefits of these approaches are also maximized when using a wider range of potential futures, including both a greater number of climate projections and more risk reduction pathways with more flexible timing for when to switch strategies. This means that these approaches are likely best used when substantial data and resources are available and the decision context warrants that level of planning and analysis.

Thresholds: Ramm et al. (2018) also demonstrate the use of thresholds in Managed Retreat assessments by establishing two criteria (maintain both the number of people exposed to the hazard and the property damage costs to below twice the current baseline) that must be met for a potential risk reduction option to be considered. This type of approach can be useful when substitutability between values is not acceptable (e.g., loss of life, Indigenous cultural values) or to effectively change the relative importance of one or more values. When combined with a flexible pathways approach, this also allows for identifying when in the future these thresholds would be crossed, which can be useful for planning how long a given strategy may be viable and deciding when switching to another would be needed (e.g., when the risk/costs of protection are no longer acceptable and Managed Retreat may be necessary).

Comparing CBA, ROA, and RDM: RDM is most useful for exploring uncertainties and finding solutions that work across the greatest number of potential futures, even though it may not be the optimal solution for any one future. In contrast, ROA and CBA both attempt to identify an optimal solution, but ROA is most beneficial when there is an opportunity to delay implementation, or the staging of implementation, and useful information to improve decision-making will be gained over this time. Both ROA and RDM require substantially more information on the quantification of uncertainties, which often isn't available, especially for longer term climate projections. When this information isn't available, or the additional time and expense of ROA or RDM are not justified by the decision context, CBA is likely the preferable approach to assessing the monetary impacts of the proposed risk reduction options.


RuudMorijn/iStock

Be Mindful and Consistent With Assessment Context and Parameters

While academic case studies can be valuable as demonstrations of new and varied approaches, the nature of the studies themselves also offers some lessons for Managed Retreat assessments in B.C.

First, academic Managed Retreat assessments are often of hypothetical case studies or of hypothetical retreat programs in real locations. In both circumstances the assessments are typically removed from the context of the larger decision-making and retreat planning processes in that location. Where a study is able to make assumptions about the most important values (e.g., using the top five 'Lived Experience' values from previous research[84]), identifying those values and how best to measure them is just as, or more, important in real world retreat assessments. The community, political, and biophysical contexts will have a large impact on how an assessment is carried out, which typically is not addressed in academic studies.

Second, the parameters used in academic Managed Retreat assessments are typically assigned arbitrarily, or based on precedent, such as using standard discount rate and infrastructure lifespan time horizons. Most studies use long time frames of 75 to 100 years and low discount rates from 0% to 3.5%. Sensitivity analyses are also common practice and are useful for demonstrating the impacts of these decisions on the assessment outcomes. For example, one study that tested different assessment time horizons found that the same project could show a Net Present Value (NPV) of -£23.9 million over a 25 year period, but a +£37.1 million NPV over a 100 year period, differences which could lead to very different decisions based on time frame alone[8].

Third, the assessment scope is typically focused at the community level, rather than considering wider societal impacts, but the studies are not always consistent. One example of this is a regional-scale study that includes the decrease in municipal property tax as a loss, but also includes increased recreational benefits across the region as a benefit of retreat. Increased clarity on the choice of scale used and better consistency in its application is one area where BC Managed Retreat assessments could improve on most academic case studies.

5

Key Principles for Managed Retreat Assessment and Decision-Making

As described throughout this document, there is no one-size-fits-all approach to Managed Retreat assessment and decision-making, and therefore there is no single methodology that will be appropriate in all cases. However, there are some general recommendations and key principles that can help to design and implement a successful decision-making process for Managed Retreat.

01

Context-Specific: The processes of both assessment and decision-making for Managed Retreat should be designed for the specific context and nature of the decisions being made. Even within the same Managed Retreat project, an assessment or decision-making process intended for one purpose or group may be inappropriate for another.

Key areas where this could be expressed include: the level of effort, time, and resources required; which tools/techniques, or combinations thereof, are used; which values are considered, how they are measured, and how they are weighed/prioritized against each other; who is involved and what roles they play; how many scenarios are assessed and at what level of detail, and how are the scenarios generated; and, how the final decision is ultimately made.

02

Community-Driven: Community engagement and co-production should be incorporated as fully and at as many stages as possible in both developing and executing the decision-making and assessment processes for Managed Retreat, potentially including all of the areas listed under Principle #1.

03

Process Over Outcome: The process of a CBA or MCDA is often more valuable than the final outcome, and it is important to design the process to maximize these benefits.

04

Creative and Community-Driven Scenarios: The development and comparison of proposed risk reduction scenarios should encourage creative and varied solutions that are driven by community values and input, and that achieve other societal goals where possible.

05

Center Community Values and Equity: Assessment and decision-making should be based on the community's values and achieving equitable outcomes. Exposure to natural hazards, and the impacts of risk reduction projects, often disproportionately affect lower income and equity-seeking populations, and addressing these inequities should be a priority in managed retreat planning and decision-making.

06

Understand and Address Uncertainty: Major sources of uncertainty should be identified and systematically addressed in all assessments. Sensitivity analyses should be conducted for all parameters and metrics where the outcome could be significantly affected by a change within a reasonable/expected range of variation.

07

Consider Multiple Tools, Approaches, and Inputs: A CBA will provide useful information in most decision-making contexts, but should not be the only input to a decision. Instead, CBAs, and other similar assessments, should be used alongside other tools and techniques, like MCDA, and Adaptation Pathways, in a broader and inclusive decision-making process.

08

Understand Limitations: It is important to understand and consider the choices, assumptions, uncertainties, and limitations involved in all CBAs, MCDAs, and other assessments when interpreting and comparing results and deciding whether they apply to the scenario in question.

09

Proactive Planning: Where possible, planners and decision-makers should attempt to complete as much communication, community engagement, planning, and assessment as possible prior to experiencing a flood, regardless of whether preemptive retreat is desired or realistic.

10

Learning and Adaptive Management: Decision-making processes surrounding retreat are likely to be iterative and require repeating steps or stages as new information becomes available and new relationships are built. Be sure to build learning and adaptive management into the process to ensure that these opportunities are not lost and that lessons are captured and implemented for future Managed Retreat projects.

6

Framework for Managed Retreat Assessment and Decision-Making

The framework below provides a visualization of how the findings and recommendations in this report can be put into action when faced with a decision involving Managed Retreat or similar measures.

As noted in the Key Principles above, contextualizing a CBA, MCDA, or other assessment tool to each location and decision-making context is key, as shown by the framework being heavily weighted toward the steps leading up to completing the assessment itself. Although this report focuses on the use of CBA and MCDA, these tools are only helpful if they align with the questions being asked and the values and worldview of the community.

The framework also highlights the importance of using multiple complementary tools and sources of information when making decisions, and the importance of community engagement at all stages of the process. Making a decision that goes against the recommendation of a CBA or MCDA is not an indication that the assessment was wrong or a waste of resources. These assessment processes are meant to provide useful information and generate discussion, not determine the final outcome or limit options.

Despite the need for flexibility in Managed Retreat assessment and decision-making to fit the project and decision-making context, a number of good practices have been identified, as summarized in the key principles and framework. **As Managed Retreat is likely to become increasingly necessary as climate change continues, and there is potentially great benefit in proactively preparing for retreat, codifying and implementing these practices prior to the next major flood could have significant benefits for the affected communities.**

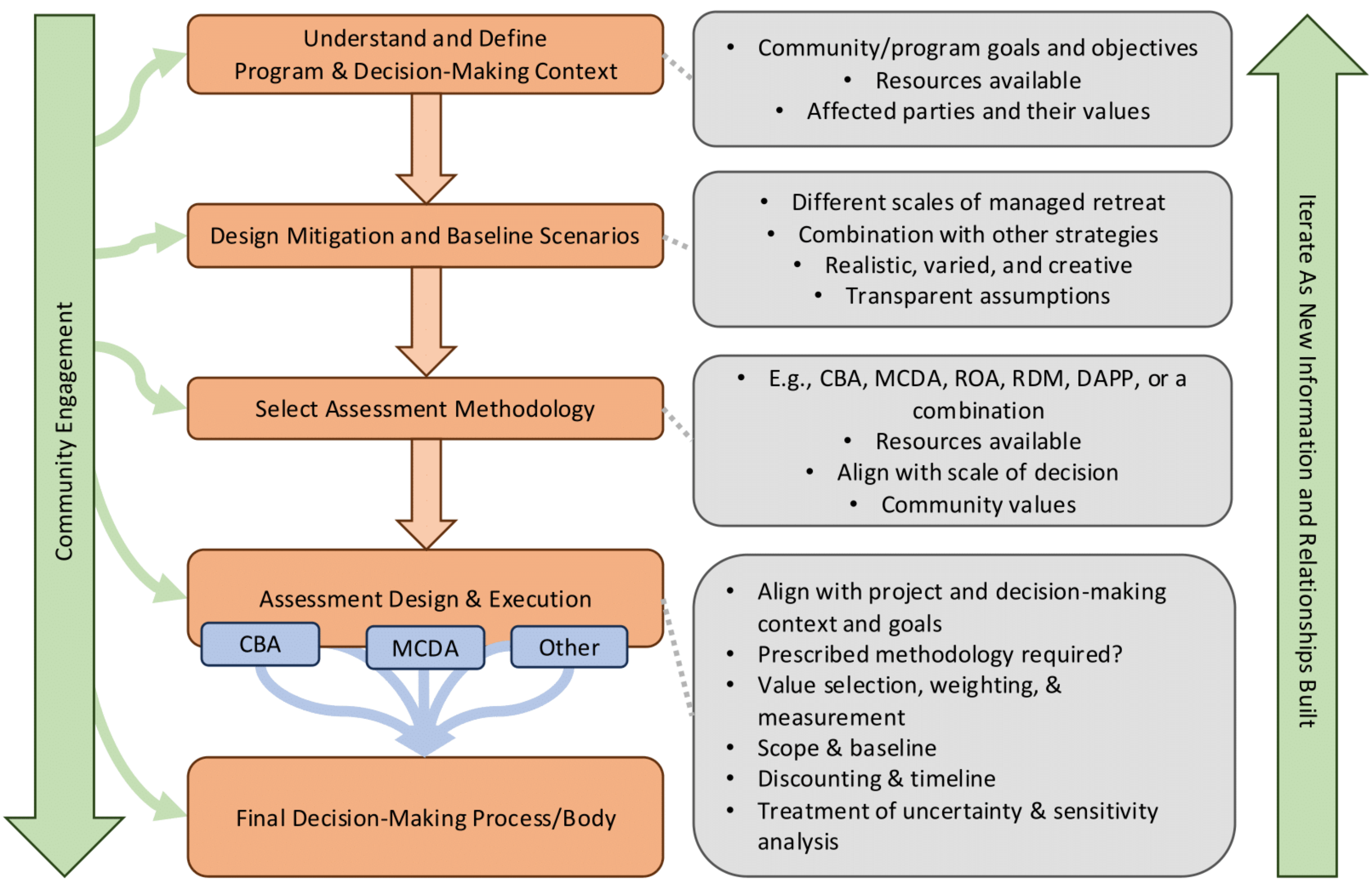

Figure 9: Managed Retreat Assessment and Decision-Making Framework

End Notes

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Appendices

Appendix 1: CBA Guidelines and Guidance Documents

<table>
<tr><th>Guidance Document</th><th>Source</th></tr>
<tr><td>Disaster Mitigation and Adaptation Fund: Applicant Guide
This web page provides guidance on applying for DMAF funding, including a short explanation of how to complete the required Return on Investment (ROI) calculation and how to include additional project co-benefits.</td><td>Canadian Disaster Financial Assistance Fund (DMAF)</td></tr>
<tr><td>Guidelines on undertaking a comprehensive analysis of benefits, costs and uncertainties of storm drainage and flood control infrastructure in a changing climate
The NRC developed this extensive guidance document is response to the highly inconsistent quality of economic assessments in DMAF applications, and includes:
• A high quality overview of CBA methodology for flood risk reduction projects, as well as highly detailed descriptions of each step in the attached appendices
• Discussions of many of the CBA challenges discussed in this document, including valuing non-market impacts, choosing a discount rate, and dealing with uncertainty (including Real Options Analysis)
• Five case studies including a range of different scales (e.g., national-level policy to municipal projects) and flood risk reduction approaches, although none are directly focused on Managed Retreat.</td><td>Canadian National Research Council (NRC)</td></tr>
<tr><td>FEMA Benefit-Cost Analysis (BCA) Guidance
This website includes a range of CBA supports, including:
• Details for completing a BCA for FEMA funding, including instructions for the 'Streamlined' process for 'substantially damaged' buildings
• A link to download the FEMA BCA Toolkit, an Excel spreadsheet based tool that walks users through the CBA process
• Training materials related to the classroom course Introduction to Benefit-Cost Analysis</td><td rowspan="2">US Federal Emergency Management Agency (FEMA)</td></tr>
<tr><td>Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs
The FEMA BCA Toolkit is based on these US Office of Management and Budget cost-effectiveness guidelines, which offer guidance on common CBA issues like discount rate, treatment of inflation, uncertainty, and distributional effects.</td></tr>
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<tr><td>The UK Green Book
The Green Book provides guidance for the appraisal of public policies, programs, and projects in the UK. The guidance is based around CBA, but emphasizes the full option development and decision-making processes, rather than relying just on CBA. It also includes useful sections on:
• Generating options and refining to a short-list of options for appraisal
• Valuation of costs and benefits
• Non-market valuation, including environmental capital, recreation, health, and flood risk and coastal erosion, among others
• Unmonetizable values, including the use of MCDA as a supplement but not a replacement for CBA
• Place-based assessments that require different scales of assessment
• Distributional effects and weighting
• Uncertainty, Optimism, Bias, and Risk
• Discounting
• Supplementary guidance available on specific topics, such as Optimism Bias, Environmental Impacts, Risk (The Orange Book), Infrastructure, Climate Change, and Wellbeing</td><td rowspan="3">United Kingdom Treasury</td></tr>
<tr><td>Accounting for the Effects of Climate Change: Supplementary Green Book Guidance
This supplement provides additional context for climate change adaptation appraisals, including risk assessments, developing options, dealing with uncertainty, and a comparison of alternative tools including MCDA, ROA, RDM, and Portfolio Assessment.</td></tr>
<tr><td>Wellbeing Guidance for Appraisal: Supplementary Green Book Guidance
This supplement greatly expands on the non-market and unmonetizable values sections from the Green-book in the form of wellbeing assessments. The guide recognizes a wide range of contributors to wellbeing, including physical and mental health, relationships, connection to community, livelihood, education, and other economic and governance factors. A range of methods for estimating wellbeing effects are reviewed (e.g., market prices, revealed preference, stated preference, subjective wellbeing), and recommendations are given for when each is appropriate, or when non-monetized wellbeing impacts should be considered separately.</td></tr>
<tr><td>Managed Retreat Components And Costing In A Coastal Setting
This 2019 Masters Thesis presents a costing framework that provides a useful starting point for a Managed Retreat CBA or MCDA. Although it focuses on impacts to buildings and infrastructure, it does include all stages of the retreat process, from community engagement through to land rehabilitation and maintenance. It also describes the various valuation approaches (e.g., market pricing, hedonic pricing, contingent valuation, travel cost) and recommends when each is appropriate, as well as providing a useful summary of the current state of Managed Retreat research.</td><td>Samuel Olufson, University of Wellington</td></tr>
</table>

Appendix 2: Tools and Approaches to Improve Managed Retreat Decision-Making & Implementation

Approaches and Tools	Challenges Addressed	Description
Deep Engagement, Collaboration, and Broad Participation	Contested Goals and Objectives Equity Concerns Poor Experiences Public Opposition Reactive Retreat	Early, deep, collaborative, and broad community engagement is the single most important approach to addressing most Managed Retreat challenges. Engagement should include all stages and aspects of planning, decision-making, and implementation, include all affected parties where possible, provide resources to allow all parties to participate, and be collaborative and meaningful rather than symbolic. Benefits include: Better identification of values, interests, challenges, and options; sense of 'buy-in' to the process; increased likelihood of proactive retreat where appropriate; improved transparency; and, improved understanding of risks and trade-offs.
Scenario Planning	Equity Concerns Poor Experiences Public Opposition Reactive Retreat	With many flood risk reduction measures (and combinations of measures) available, it is important to design and consider a wide range of creative risk reduction options. Many Managed Retreat challenges can be mitigated through careful project design, such as: combining protection, accommodation, and retreat measures in a holistic flood management plan; innovative use of retreat lands, such as cultural experiences and floodable parks; 'buy and rent back' programs that allow residents to continue living in their homes until flood risks become unacceptable and that help to pay for program costs; considering different scales of retreat; or, compensation design and relocation supports that reduce the impacts of relocation and address equity concerns.
Proactive Planning	Implementation Issues Poor Experiences Public Opposition Reactive Retreat	Proactive planning has benefits whether retreat is ultimately implemented pre- or post-disaster. While uncertainty in flood timing makes it possible that proactive retreat will occur potentially many years before the next major flood, this approach avoids all of the negative impacts and costs of experiencing a flood and allows time for broader societal goals to be included in retreat planning, such as economic development, ecological enhancement, and addressing inequities. Designing retreat triggers based on current conditions and climate change forecasts, along with the community's risk tolerance, can further help to minimize the negative impacts of proactive retreat. For post-disaster retreat, proactive planning reduces implementation delays (which are one of the major causes of poor retreat experiences), increases time for community engagement to improve program design and buy-in, and improves the chance that other societal goals can be achieved alongside retreat, rather than focusing solely on expediting the relocation process.

Communication and Transparency	Implementation Issues Poor Experiences Public Opposition	Clear communication and transparent program design, decision-making, and implementation can mitigate many of the major causes of poor retreat experience and implementation challenges. Communication and transparency are also necessary components of deep community engagement, described above. Examples of good practices include: clear explanations of why some homes/areas are eligible or ineligible and how the compensation program was designed; each household being assigned a consistent point of contact throughout the program; guidance and supports both pre- and post-relocation; and, availability of assistance in multiple languages and/or cultural contexts, as needed.
Compensation Design	Implementation Issues Poor Experiences Public Opposition	Ideal compensation design will vary depending on retreat program resources and objectives. Some factors to consider include: providing sufficient compensation to relocate to a similar home in an area of lower natural hazard and social vulnerability; supports for homeowners, renters, and those lacking stable housing; including post-retreat supports; maximizing project benefits for the available budget; avoiding sense of unfair subsidy for wealthy homeowners; encouraging retreat at a neighbourhood-scale rather than building-by-building; and, being clear and transparent in how compensation levels are set. It is important to note that a given compensation program may benefit some program goals while reducing others, such as addressing equity issues and providing post-retreat supports may reduce the level of risk reduction possible with a given budget, or high compensation levels may be necessary to incentivize coastal residents to relocate which may be seen as a wealth subsidy to the surrounding community.
Funding Program Design	Implementation Issues Reactive Retreat	Most funding programs for Managed Retreat are discretionary and only become available post-disaster or when specific requests are made, which limits proactive retreat planning and implementation. Providing flexibility in the timing, amounts, and what the funds can be spent on (e.g., engagement and post-disaster supports rather than only property acquisition) allows for earlier planning and execution, and for the design and implementation of place-based retreat programs. Where funding programs specify valuation methodologies, they should align with program objectives and consider how they affect the project feasibility and outcomes (e.g., pre- vs post-flood valuations, compensation caps).

Case Study Location	Assessment Type(s)	Options Compared/Assessed	Costs Assessed	Benefits Assessed	Parameters and Outcomes
Grand Forks, BC[82]	CBA/ROI for DMAF Funding Application	Assessment of a single preferred option, made up of buyout & various diking, pond, culvert, and other flood protection measures.	Monetary: Land Acquisition Structural Flood Mitigation Costs: structure demolition; dike removal; road raising; trail dike; road dike; culverts & headwall; ponds, settling forebay & ditch; erosion protection (rip-rap & bio-engineering); general requirements; contingency (20%); Phase II Environmental Site Assessment Natural Flood Mitigation: surface restoration; underground restoration; demolition; contingency (20%); hazardous building materials assessments	Monetary: Flood damage avoided. Calculated as AAD using comprehensive flood probability distribution. Only includes damages that would be affected by DMAF funded projects. Damage avoided due to projects with other funding was not included in this calculation. Non-monetary benefits are listed but not assessed. Includes: Natural capital; green space; green transportation route; leisure; increased investment confidence; increase resilience; reduced loss of life; reduced affected population in future floods; reduced impact to essential services; reduced economic losses	Time Horizon: 75 years for sea wall; 100 years for earth berms; 150 years for dike removal and buyout Discount Rate: 0%, as specified for DMAF ROI calculation Scope: Limited to only the costs and benefits related to DMAF funded projects. ROI: 3.4:1

Case Study Location	Assessment Type(s)	Options Compared/ Assessed	Costs Assessed	Benefits Assessed	Parameters and Outcomes
Merritt, BC [85]	MCDA	7 Options Compared: 1: Do nothing, status quo 2: Full floodplain retreat 3: Waterside diking 4a, 4b, 4c: Combination diking (different combinations of waterside and setback diking) 5: Combination diking (optimized with City input)	Technical: Is it technically sound? Does it effectively reduce the City's flood risk? Construction: Is it feasible to construct? Are there potential conflicts? Environment: Is it environmentally friendly and sustainable? Land Use: Does it impact a significant area? Economic: Cost-effectiveness		Option 5 chosen as preferred option by City Council.
	CBA/ROI for DMAF Funding Application	Assessment of a single preferred option (Option 5 from MCDA: Combination diking) compared to a baseline scenario. Baseline: Assumes number and types of dwellings remain constant over the entire forecast period.	Direct Project Costs: Construction, Buyouts, Demolition, Reclamation, Operation and Maintenance Environmental, cultural, and heritage costs are assumed to be mitigated at a relatively low cost and unlikely to change the outcome of the CBA and ROI calculations	AAD Averted: Includes: Direct residential, non-residential, and municipal asset & infrastructure damages; Indirect damages (Residential displacement, business disruption, emergency services & cleanup (including impacts to vulnerable populations, increased crime, and temporary housing); Intangible damages (public physical and mental health, quality of life) was assessed as a set value per household per year. Other non-market impacts listed but not monetized: School closures; environmental impacts; and heritage & cultural impacts	Time Horizon: 100 Years Discount Rate: 7%, 4%, 3%, plus 0% for DMAF ROI calculation Sensitivity Analysis: Calculated percentage change in estimated costs and avoided damages needed to change NPV from positive to negative, in additional to multiple discount rates. NPV was found to be positive for discount rates up to 4%, but negative for a discount rate of 7%. ROI: 7.1:1

Case Study Location	Assessment Type(s)	Options Compared/ Assessed	Costs Assessed	Benefits Assessed	Parameters and Outcomes
Calgary, AB [53]	MCDA ("Triple Bottom Line")	13 Options Compared 0: Baseline 0a: Non-structural 1: SR1 1a: SR1 + Downtown barrier 2: SR1 + Bow Reservoir 3: Bow Reservoir + Elbow barriers 4: SR1 + Bow barriers 4a: 4 w/ groundwater controls 5: Barriers on Bow + Elbow 6: Flood-way buyouts 7: SR1, Bow Reservoir, Select Barriers	4 Categories, each with sub-criteria Social (7 Criteria): Complete communities; Equitable protection; Vulnerable populations; River aesthetics; Recreation access; Emergency access; Risk transparency Environmental (3 Criteria): Water security; Riparian health and ecosystem function; Water quality and contamination prevention Implementation (4 Criteria): Timeliness of implementation; Adaptability/Flexibility; Jurisdictional control; Regulatory complexity Economic (4 Criteria): Economic environment; Economic efficiency; Damages averted; Total cost (simplified CBA, including residual AAD)		Scoring: Each criteria scored from -6 to +6. Scores tallied for each scenario under each category. Carried out by the project team over two sessions. Weighting: Each category assigned equal weighting of 12 points that is divided among the sub-criteria. Results: The top 3 scoring options were 7, 2, and 1, with Option 6 (Floodplain Buyouts) scoring the lowest and ranked last. See Figure 5 for full scoring results.

Case Study Location	Assessment Type(s)	Options Compared/ Assessed	Costs Assessed	Benefits Assessed	Parameters and Outcomes
Calgary, AB Continued	CBA	2 Options Compared: McLean Creek flood storage project ("MC1") and Springbank flood storage project ("SR1")	Direct Project Costs: Mobilization; utility and road work/relocation; care of water; diversion structure and channel; off-stream storage dam; wetland compensation; aquatic habitat management plan; engineering, environment, and engagement; contingencies; permitting; administration Land Acquisition For SR1: Very detailed process that compares multiple estimation methods. For MC1: Attempt to estimate replacement cost of lost recreational land. Operation and Maintenance: 1% of construction costs Non-monetary benefits are listed but not assessed. Includes: Biophysical impacts; social impacts; aesthetic impacts; implementation challenges (complexity, flexibility and integration with other measures), other	Average annual damages (AAD) averted. Includes: Residential, non-residential, and infrastructure damages; Indirect damages (e.g., traffic disruption, habitat restoration, emergency response, waste disposal); Intangibles (e.g., public health) as a set amount per residence per year. Methodology also includes groundwater damage outside of river floodplains. Annual Agricultural Lease-back potential Non-monetary benefits are listed but not assessed. Includes: recreation; drought mitigation; disaster prevention (reduces current/future losses and loss of life); biophysical impacts; social impacts; aesthetic impacts; implementation challenges (complexity, flexibility and integration with other measures); other	Time Horizon: 100 Years. Construction costs are spread over first 2-6 years, depending on the option. Benefits and O&M being after construction complete. Discount Rate: 4% Scope: City of Calgary boundaries Results: SR1: NPV = $264,065,000 Benefit/Cost Ratio = 1.68 MC1: NPV = $175,998,000 Benefit/Cost Ratio = 1.44 Note: If land value was included in MC1 costs, then the B/C ratio would decrease to 1.26.

Appendix 4: Selected Academic Case Study Assessment Details

Academic CBA Case Study & Assessment Type	Options Compared	Costs Assessed	Benefits Assessed	Parameters and Outcomes
André, C., Boulet, D., Rey-Valette, H., & Rulleau, B. (2016) 61 CBA	5 Options Compared: Control with minimal change; Defense; Standard Managed Retreat; Retreat with division of ownership; Retreat with buy and lease back Location: Fictional coastal town in France, population 6500	Project costs: Buyout (market) + 10% for relocation fees; Demolition (buildings, infrastructure); Beach nourishment; Riprap installation Flood damage (non-retreat scenarios) Related Costs: Decrease in tourism; Tax implications of population change; Loss of seagrass meadows; Renaturing the beach; Property transfer and leasing management; Maintaining leased houses; Loan costs; Crisis management (10% of property damage); Psychological effects (increase in psychotropic drug use); Decrease in property value from smaller beach (protection)	Scenic, recreation, and environmental gains (more tourism) Community revitalization (more tourism) Flood damage (and all other associated costs) avoided with retreat Tourism Increase & WTP for beach conservation	Time Horizon: 50 Years Discount Rate: 2.5% Sensitivity Analysis: +/- 20% for: cost of defense structures; beach nourishment; purchase price for housing; tourism income; number of beach users +/-50% for value of seagrass meadows WTP for beaches (1 to 5 euro/visit) Results: Results calculated for 'classic' vs. 'enhanced' CBA with addition costs/benefits (e.g., seagrass losses) 'Classic' CBA: Protection preferred option (NPV = €29,289,247). Negative NPV for all relocation options. 'Enhanced' CBA: Leasing relocation preferred option (NPV = €9,055,632). Negative NPV for protection and standard relocation. Positive NPV for division of ownership and lease-back relocation.

Academic CBA Case Study & Assessment Type	Options Compared	Costs Assessed	Benefits Assessed	Parameters and Outcomes
Cardona, F. S., Ferreira, J. C., & Lopes, A. M. (2020) [91] CBA	3 Broad adaptation options compared: Defense, Accommodation, and Retreat Location: Coastal Portugal	Defense: Ongoing maintenance is only cost assessed Accommodation: 30% of property value every 25 years Retreat: Total construction costs, plus demolition costs for buildings in use (derelict buildings ignored) Indirect Costs: Listed but not assessed	Indirect Benefits: Listed but not assessed	Time Horizon: 50 Years Discount Rate: 3% Results: Cumulative costs: Defense + Accommodation: €276 million Accommodation: €164 million Defense: €112 million Relocation: €75 million
Meyer, V., Priest, S., & Kuhlicke, C. (2012) [100] CBA + Qualitative Transaction Cost Assessment	Two Separate Case Studies: 1) Resettlement vs. ring dike of a small town (Erlln) 2) Protection wall vs. warning system vs. combination (Grimma) Location: Erlln and Grimma, Mulde River, Germany	Dike construction costs (No maintenance costs considered) Buyout costs at market value Transaction costs (Qualitative scale from 0-5) (e.g., information costs, planning and design, meetings, communication, participation processes, negotiations and solving conflicts, legal enactment and monitoring)	Reduction in AAD Calculated using depth-damage models and a range of flood return periods. Min, median, and maximum estimated provided.	Time Horizon: 100 Years (plus sensitivity analysis to 150 years) Discount Rate: 3% (plus sensitivity analysis) Results (Using Mean AAD): For Erlnn, both options had a negative NPV, but the ring dike was less negative. Ring dike: NPV = € -2,167,400 Resettlement: NPV = € -4,868,700 For Grimma, all three options had a negative NPV. The warning system had the least negative NPV, but was also the least effective (providing only 2.1% of the protection goal vs. 100% for the protection wall). Protection wall: NPV = € -9,759,000 Warning system: NPV = € -10,200 Combination: NPV = € -9,962,400

Academic CBA Case Study & Assessment Type	Options Compared	Costs Assessed	Benefits Assessed	Parameters and Outcomes
Revell, D., King, P., Giliam, J., Calil, J., Jenkins, S., Helmer, C., Nakagawa, J., Snyder, A., Ellis, J., & Jamieson, M. (2021) 92 CBA	5 Options Compared: Coastal armouring; Beach Nourishment; Living Dunes; Groins with Sand Nourishment; Managed Retreat (including a purchase and leaseback option) Location: Imperial Beach, California	Project costs: Construction; maintenance (including higher costs as beach widths narrow); Removal as necessary. Temporary reduction in ecosystem services after beach nourishment Tax revenue impacts Impacts to private and public land & infrastructure	Loss Averted: Property damage from flooding & erosion; Calculated using depth-damage curves as a % of replacement cost. Recreational value (based on attendance rates, “day use value” and modeling of changing use with decreasing beach width; combined with survey data on spending & tax revenues) Ecosystem services (valued using replacement cost)	Time Horizon: 85 Years Discount Rate: 1% (Plus sensitivity analysis) Sensitivity Analysis: Discount Rate (0 to 5%); Recreational Value; Beach attendance; Ecosystem Service Value (o to 200%); Nourishment/ Restoration Costs; Beach Width Results: Ranking of options for Narrow Beach: 1. Dunes; 2. Groins; 3. Nourishment; 4. Retreat; 5. Armouring Ranking of options for Wide Beach: 1. Groins; 2. Retreat; 3. Nourishment; 4. Dunes; 5. Armouring.
Turner, R. K., Burgess, D., Hadley, D., Coombes, E., & Jackson, N. (2007) 6 CBA	5 scenarios compared: Each scenario uses different combinations and scales of Managed Retreat and Defense. Scenarios are labeled as Hold-the-line (HTL), Business-as-usual (BAU), Policy Targets (PT), Deep Green (DG), and Extended Deep Green (EDG) Location: Humber Estuary, UK	Retreat: Capital cost; Opportunity cost of lost agricultural land Defense: Maintenance; Replacement of deficient defenses	Habitat creation Carbon sequestration Lower maintenance costs due to wave attenuation	Time Horizon: Sensitivity analysis using 25 to 100 years Discount Rate: Sensitivity analysis using static 3.5%, declining (3.5% declining to 2.5%), and hyperbolic gamma discounting Results: Although all options result in a negative NPV, EDG has the greatest benefit over hold-the-line and business-as-usual baseline scenarios. HTL NPV = £ -100.93 million BAU NPV = £ -103.93 million PT NPV = £ -92.27 million DG NPV = £ -107.92 million EDG NPV = £ -63.83 million Note: Using 100 year time horizon & declining discount rate

Academic CBA Case Study & Assessment Type	Options Compared	Assessment Criteria	Parameters and Outcomes
Lawrence, J., Bell, R., & Stroombergen, A. (2019) [35] MCDA, Real Options Analysis (ROA), & Dynamic Adaptive Pathways	Options Compared 6 'Pathways' per Coastal Unit: For each coastal unit, six pathways were evaluated. Each pathway was made of up one Short Term (0-20 years), one Medium Term (20-50 years), and one Long Term (50-100 years) action selected from four categories of action: Status Quo; Hold the line; Realignment; and Managed Retreat ('Retreat the Line'). Pathways are used to account for the ability to change strategy as conditions change. Location: Hawke's Bay, New Zealand	MCDA Criteria (All Rated on 1-5 Scale) Technical Assessment Criteria: Managed the risks of storm surge inundation; Managed the risk of coastal erosion; Ability to adapt to increasing risks; Risk Transfer Impact Assessment Criteria: Socio-economic impacts; Relationship of Maori and their culture and traditions with their ancestral lands, water, sites, wahi tapu, and other taonga; Natural environments impacts. ROA used to assess financial costs separately from MCDA. Costs: Construction and operation costs; Transition costs when moving between risk reduction actions Value For Money: Calculated by dividing the cost by the MCDA score. Measured in $1,000/MCDA Point.	Time Horizon: 100 Years Scoring: Each criterion is scored from 1 to 5. Scores are tallied for each pathway under each category. Scoring was carried out by the project team over two sessions. Weighting: Methods for assigning of weights not described. Weights were used to calculate weighted sum of criteria scores and to calculate a total 'MCDA' score for each pathway Ranks were calculated both by MCDA Points and by Value For Money to compare performance vs. cost. Results: Each scenario was evaluated and ranked for the overall MCDA, the total cost plus residual losses, and value for money (i.e., the cost per MCDA point). For one particular coastal unit, the same three scenarios were ranked first, second, and third in all three metrics. 1. Renourishment + Control Structures for all three time periods 2. Renourishment + Control structures for the Short and Medium Term periods, and 'Retreat The Line' for the Long Term period 3. Renourishment + Control structures for the Short and Medium Term periods, and Seawall for the Long Term period.

Academic CBA Case Study & Assessment Type	Options Compared	Assessment Criteria	Parameters and Outcomes
Ramm, T. D., Watson, C. S., & White, C. J. (2018) [78] Robust Decision Making (RDM) & Dynamic Adaptive Policy Pathways	5000 future scenarios generated by sampling from realistic range of several uncertainties (e.g., rate of sea level rise, timing/rate of abrupt sea level rise, rate of retreat, level of flood damage) 5 Risk Reduction Strategies Considered: Do Nothing; Barrier Protection; Changed building requirements; Land use change; Planned retreat Location: Lakes Entrance, Australia	Adaptation Objectives: The 5000 scenarios were tested against two thresholds to represent the maximum impacts tolerable to society: 1) Safety: Maintain number of people exposed to extreme flooding to below twice the current baseline. Measured using Average Annual People Exposed (AAPE). 2) Maintain property damage costs (commercial and residential) to below twice the current baseline. Measured using Average Annual Damage (AAD). 'Lived Values': A subset of pathways were also assessed using a series of qualitative factors, including relative cost, short-term political risk, rate of implementation, and the top 5 'Lived Values' of the community (which had been identified in other research), including Scenery, Natural Environment, Safety, Proximity to Water, Lifestyle. Additional Qualitative Factors: Cost; Political Risk; Rate of Implementation	Time Horizon: 90 Years (2010-2100) Qualitative Scoring: Costs and Rate of Implementation (1-3); Short-term political risk (L, L/M, M, M/H, H); Lived Values (Large Relative Loss, Relative Loss, No Change, Relative Gain, Large Relative Gain) Results: For each risk reduction strategy plus the status quo, the study reports the number of future scenarios out of the 5000 tested where the thresholds were not exceeded, as well as the median year when each of the thresholds would be exceeded. For example, under the status quo the AAPE and AAD thresholds were not exceeded in only 449 and 436 of the 5000 cases, respectively, and the median exceedance dates were both 2050. In contrast, using the retreat risk reduction option, the thresholds were not exceeded in 2052 and 2320 of the 5000 cases, respectively, and the median exceedance dates were 2090 and 2100+.

Academic CBA Case Study & Assessment Type	Options Compared	Assessment Criteria	Parameters and Outcomes
Skidmore, T. A., & Cohon, J. L. (2022) 101 MCDA	8 Alternatives Considered: Do Nothing; Improve Kivalina; 6 different community relocation options (Tachim Isua, Kuugruaq, Igrugaivik, Kiniktuuraq, Imnakuk Bluffs, Simiq) Location: Kivalina, Alaska	Costs (All Monetized): Policy cost; Property Value (Preservation); Investment Potential (All monetized) Risk to Humans (1-10 Scales): Safety Hazards; Long-Term Health Risks Environmental Protection (1-10 Scales): Depletion of Natural Resources; Destruction of Ecosystems Convenience (1-10 Scales): Flexibility to Change/Adaptation; Length of Implementation; Disruption to Community Operation; Political Feasibility; Technical Feasibility Equity and Social Justice (1-10 Scales): Fairness and Equity; Preservation of Culture and Community; Restitution	Scoring: Each criterion was scored as two hypothetical interested parties: a landowner and an environmental activist. Weights: Weights were automatically derived from criteria scores based on a standardized table. This means that criteria that were scored higher were automatically given greater weight. Results: Results are shown for each criterion and the overall scores for both hypothetical interested parties to show similarities and differences. For example, the Simiq relocation option had the strongest agreement, ranking 1st with the ‘environmental activist’ and 2nd with the ‘landowner’. In contrast the two options that do not involve relocation (i.e., Do Nothing, and Improve Kivalina) ranked 3rd and 4th, respectively, with the landowner, but 7th and 8th out of the eight options with the ‘environmental activist’.

Valuation and Measurement Methods:

- **Benefit Transfer:** Benefit transfer methods use the results of valuation studies from other locations and/or context to estimate the value in a new location/context. Depending on the valuation technique used and the differences between the locations and contexts, the values may need to be adjusted for a range of characteristics, such as wealth (e.g., GDP), characteristics of the item being valued (e.g., wetland health, forest size, beach width), and cultural differences (e.g., different risk tolerances, perceptions of nature). Whether benefit transfer is appropriate and the level of uncertainty in the adjusted values are heavily dependent on how similar the two locations and contexts are.
- **Contingent Valuation:** Contingent valuation methods estimate the 'willingness to pay' (WTP) for a given non-market benefit or the 'willingness to accept' (WTA) for a given non-market cost. WTP and WTA are typically assessed using surveys or by asking questions about relative preferences ('choice experiments'). Average WTP/WTA values are typically multiplied by the affected population to calculate a total value. Contingent valuation can be used to measure the cost or benefit assigned to practically any non-market value that the community is comfortable valuing in monetary terms, such as feeling of safety, the intrinsic value of ecosystem health, or the stress of living through a flood. However, contingent valuation surveys need to be carefully designed to avoid a bias toward the priorities of wealthier populations (who can afford to pay more or accept greater losses) or to give an implicit bias to groups who place arbitrarily high values on priority items.
- **Ecosystem Services:** Many different ecosystem service methodologies exist, but they share an overarching goal of measuring the benefits to human society from a given ecosystem, typically using monetary figures. Ecosystem services are commonly divided into provisioning services (e.g., products like wood, oil, and food), regulating services (e.g., flood regulation, water purification, pollination), cultural services (e.g., recreation, aesthetic value, spiritual value), and supporting services (e.g., photosynthesis, nutrient cycling). Ecosystem service measurements typically focus on the benefits to humanity rather than the intrinsic value of the ecosystems themselves, although non-use value can be incorporated in supporting service assessments.
- **Hedonic Pricing:** Uses statistical methods to estimate the contribution of various factors to market prices. Most commonly used to estimate the effect of different attributes on real estate values, such as proximity to water or green space, level of flood risk, or scenic views.
- **Market Price:** The price at which a good or service can be purchased or sold on the open market (e.g., labour, equipment, land).
- **Market Proxies:** The value of some non-market costs and benefits can be estimated indirectly by measuring related spending in the open market, such as increased spending on counselling or psychotropic drugs following a disaster as an estimate of psychological impacts.
- **Qualitative:** When quantification is inappropriate or not desired by the community, qualitative measures can be used, such as interviews and workshops, surveys, photographs and video, and story telling.
- **Reduced Average Annual Damages:** Uses statistical methods to estimate the average annual savings in flood damage resulting from risk reduction projects. See Section 3.1.2 for more information.
- **Regulated:** Certain costs may be regulated or controlled by external funding agencies (e.g., capped compensation levels).
- **Replacement Cost:** The cost to replace a service, item, or other benefit (e.g., creating new wetlands to replace wetlands destroyed by seawall construction, cost of stormwater treatment to replace ecosystem services of destroyed wetlands, new beach construction to replace recreation opportunities of eroded coastline).
- **Revealed Preference:** Uses actual behaviour to estimate values assigned to non-market values, such as using the additional wages workers are willing to accept to take on more dangerous work as an estimate of their valuation of personal safety.
- **Travel Cost:** The cost, including time, of traveling to a desirable destination. Travel cost can be used to establish a minimum value visitors attribute to a given location or service (e.g., amount visitors spend traveling to a beach or other attractive environment). Travel cost can be assessed through surveys or market data and average travel cost values can be multiplied by the number of visitors to a given location each year to produce a total annual value.

Common Managed Retreat Costs & Benefits

Managed Retreat Factor/Value	Value Type(s)	Cost / Benefit	Measurement	Notes
Community Engagement/ Consultation on Flood Risk Reduction Options	Economic	Cost	Market Price	Cost of community consultation, including compensation, facilities, communication, etc.
Government/Implementing Agency planning and administration	Economic	Cost	Market Price	Cost of staff and consultant time on communication, consultation, design, implementation, changes to legislation, regulation, or other rules, as needed, etc.
Flood Risk Monitoring	Economic	Cost	Market Price	Cost to monitor natural (e.g., sea level rise, streamflow, precipitation) and cultural (e.g., risk tolerance, hazard exposure) factors that could trigger retreat or other changes in risk reduction strategy.
Purchase of affected properties	Economic, or Non-market	Cost	Market Price, Regulated, Contingent Valuation, Replacement Cost	See Section 3.1.2 for more in-depth discussion. May also include legal costs, development of land covenants, etc.
Purchase of land for relocation, if needed	Economic	Cost	Market Price	Alternative land may be needed to relocate structures or to build new buildings and infrastructure. May include purchase price and transaction costs.
Demolition	Economic	Cost	Market Price	Cost to demolish buildings and remove debris.
Land rehabilitation, ecosystem restoration	Economic	Cost	Market Price	Cost to change land use as determined during retreat planning.
Land/ecosystem maintenance	Economic	Cost	Market Price	Ongoing cost to maintain new land use post-retreat.
Relocation of buildings and infrastructure, as feasible	Economic	Cost	Market Price	Some buildings and infrastructure may be able to be relocated rather than demolished.
Providing temporary housing	Economic	Cost	Market Price	Temporary housing may be needed post-flood or during relocation.
Activation of property covenants	Economic	Cost	Replacement Cost	Cost to property owner represented by the reduction in the ability to use the property to its full potential.

Managed Retreat Factor/Value	Value Type(s)	Cost / Benefit	Measurement	Notes
Relocation or rebuilding of community assets	Economic	Cost	Market Price	Larger scale retreat projects may involve moving schools, community halls, etc., that will need to be replaced in new location.
Reduction in municipal services and maintenance	Economic	Benefit	Market Price	Municipalities could see savings in no longer having to provide services (e.g., water, sewage, garbage, road maintenance) to the affected area.
Change in recreational opportunities	Non-Market	Benefit or Cost	Travel Cost, Contingent Valuation, Replacement Cost, Qualitative	New land use may increase or decrease recreational opportunities for community and/or the broader area.
Change in ecosystem services	Non-Market	Benefit or Cost	Ecosystem Service Methodologies, Contingent Valuation, Replacement Cost	New land use may increase or decrease ecosystem services provided (e.g., water quality, pollination, carbon sequestration, erosion protection).
Environmental Impacts	Non-market	Benefit or Cost	Contingent Valuation, Qualitative	While ecosystem service measurements tend to focus on benefits to humanity, non-use impacts can also be considered (e.g., habitat, existence value).
Flood protection of neighboring properties	Market	Benefit	Reduced average annual damages (AAD), Hedonic Pricing (Increase in property value)	Naturalizing the floodplain, or building nature-based flood mitigation works on the retreat lands, can provide additional flood protection to neighboring properties. This benefit could also be captured under ecosystem services, particularly if no flood works are constructed. Reducing flood risk may also increase adjacent property value.
Loss of connection to place	Non-market	Cost	Qualitative, Contingent Valuation	Relocation can have negative impacts on identity and wellbeing related to personal and cultural connections to place.
Loss of community connection and supports	Non-market	Cost	Qualitative, Contingent Valuation	Relocation, especially when done on an individual level rather than whole community basis, can result in losing community connections and supports, which can have a negative impact on wellbeing (e.g., social life, emergency supports, community capital).
Greater sense of safety	Non-market	Benefit	Qualitative, Contingent Valuation	Retreat can increase wellbeing by providing a greater sense of safety compared to living under flood risk.

Managed Retreat Factor/Value	Value Type(s)	Cost / Benefit	Measurement	Notes
Reduction in flood response and recovery spending.	Market	Benefit	Market Price	By eliminating flood risk, retreat reduces the cost of flood response and recovery compared to the status quo and compared protection- and accommodation-based approaches.
Reduces psychological impact of experiencing a flood.	Non-market	Benefit	Qualitative, Contingent Valuation, Market proxies (e.g., counselling, psychotropic drug use)	Psychological impacts can make up a substantial portion of total flood impacts. By eliminating flood risk, retreat reduces the chance of psychological harms compared to the status quo and compared to protection- and accommodation-based approaches.
Reduces physical health impacts, including death, from flood events	Non-market	Benefit	Contingent Valuation, Revealed Preference	By eliminating flood risk, retreat reduces the chance of health impacts and death during and after flood events (e.g., pollution) compared to the status quo and compared to protection- and accommodation-based approaches.
Business disruption	Market	Benefit	Market Price	By eliminating flood risk, retreat reduces the chance of business disruption during and after flood events compared to the status quo and compared to protection- and accommodation-based approaches.
Increased value of adjacent properties	Market	Benefit	Market Price	In addition to increased value due to reduced flood risk (see above), increased recreation and amenity values may increase the value of properties adjacent to the affected lands.
Insurance impacts	Market	Benefit	Market Price	Retreat can reduce insurance payouts and reduce insurance premiums.
Population displacement	Non-market	Benefit or Cost	Contingent Valuation	In addition to temporary housing costs, displacement has intangible wellbeing impacts. Preventing post-flood displacement can be a large benefit of pre-emptive retreat, whereas post-flood retreat can extend displacements longer than other risk reduction measures.
Cultural and educational opportunities	Non-market	Benefit	Contingent Valuation, Qualitative, Travel Cost	Post-retreat land uses can include cultural and/or education benefits (e.g., traditional food access, environmental and/or cultural educational signage/programs).

Appendix 6: Community-Led Managed Retreat: Assessment and Decision-Making Brochure

For a synthesized version of this report, please find the 2-page summary called *Community-Led Managed Retreat: Assessment and Decision-Making*. The synthesized version can be found on the next page.

Community-Led Managed Retreat: Assessment and Decision-Making

What is Community-Led Managed Retreat (CLMR)?

CLMR is the strategic relocation of people and structures out of harm's way to reduce natural hazard risk and adapt to climate change. Community support is the most important factor for achieving positive outcomes for both the affected households and the broader community when implementing Managed Retreat.

BC Flood Strategy Intentions Paper Action 4.4: Enhance Investments in Community-Led Retreat

"Critically, affected communities must support such measures and be involved in leading change to enable success."

Why Consider Community-Led Managed Retreat?

- CLMR fully eliminates flood risk, unlike flood protection which can overtop or fail
- Lower maintenance costs than building hard infrastructure
- Land after retreat can provide environmental, social, cultural, and flood protection benefits for the wider community
- After retreat, the available land can provide environmental, social, cultural, and flood protection benefits for the wider community
- Although most commonly used to move homes out of floodplains, CLMR can be used for many different natural hazards (e.g., flood, landslides, forest fires) and types of values (e.g., infrastructure, culturally significant sites)

Supporting Managed Retreat Decision-Making

Reducing natural hazard risks, such as coastal and inland flooding, can be done using various approaches, including protection, accommodation, retreat, and avoidance, each of which can take many forms and be used individually or in combination. Communities considering CLMR must assess its complex trade-offs, cost, and benefits to inform collective decision-making. This summary introduces two of the most common tools used to help make transparent and defensible decisions based on community values: Cost-Benefit Analysis and Multi-Criteria Decision Analysis.

Cost-Benefit Analysis (CBA)

Cost-Benefit Analysis (CBA) compares all of the costs and benefits of each available option that can be measured in dollars, with the aim of identifying which one produces the greatest net benefit to society (i.e., where benefits outweigh the costs by the greatest amount). CBA results are often expressed as a ratio of benefits to costs (e.g., 7:1, meaning the expected benefits are 7 times greater than the costs), or as a Return on Investment (ROI), which is a simplified form of CBA focused on the financial mitigation costs and estimated reductions in future flood damage.

CBAs are a relatively thorough, transparent, and accepted way to compare alternatives and demonstrate efficient use of public funds, however it is difficult or impossible to monetize some environmental, social, and cultural costs and benefits. This is important for CLMR, which can have large intangible costs (e.g., losing connections to place/community) and benefits (e.g., improved feeling of safety and connection to nature). Most CBAs also discount the future compared to today, meaning that present day impacts are valued more highly than future ones. This adjustment may not make sense for important 'timeless' values like public safety, sense of community, spiritual ties to land, and a healthy environment.

Multi-Criteria Decision Analysis (MCDA)

CBAs provide valuable information but are best used as part of a more holistic decision-making process. One such approach is Multi-Criteria Decision Analysis (MCDA), which compares proposed options across a range of quantitative and qualitative factors. MCDA and CBA work well together, using a CBA to measure financial impacts and MCDA to add non-monetary factors.

MCDAs can provide more holistic comparisons, build understanding of trade-offs, and encourage discussion. MCDA comes in many forms to accommodate different types of decisions, values, levels of community participation, and resources available. MCDA is most effective when built on a collaborative, inclusive process where the community helps to decide which values are important, how to measure those values, and how to weigh them against each other.

However, MCDA's collaborative process can be time consuming and expensive, choosing the best form of MCDA can be difficult (e.g., should a high scoring area offset a low scoring one, or is moderate performance in all areas preferred?), assigning values and weights is open to bias and manipulation by influential people and groups, and it may still not capture values that cannot be scored or where information cannot be publicly released.

Multiple Accounts Analysis (MAA)

MAA is a form of MCDA that has been used in B.C. for various natural resource management issues. MAA uses four 'Accounts' to divide the values under consideration (Technical, Economic, Environmental, and Socio-Economic) and uses a relatively easy to implement scoring system.

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Examples of CBA and MCDA for Managed Retreat	
Grand Forks, BC *CBA/ROI*	A buyout of residents in the highest risk areas of Grand Forks was conducted as part of a wider flood mitigation plan following a major flood event in 2018. A simplified CBA was conducted to fulfill the ROI calculation requirement when applying for support from the Federal Disaster Mitigation and Adaptation Fund (DMAF). The study found the return on investment (ROI) was 3.4 for the Grand Forks flood mitigation plan (i.e., the benefits were 3.4x the costs).
Calgary, AB *MCDA & CBA*	Calgary used both MCDA and CBA to select mitigation projects following flooding in 2013. MCDA ("Triple Bottom Line") was used to compare 13 mitigation options, including Managed Retreat. A detailed CBA was then used to choose between the top two options.
Merritt, BC *MCDA & CBA/ROI*	City of Merritt used MCDA to select a preferred mitigation strategy post-flooding in 2021, and a CBA/ROI to support the implementation and funding of this plan. MCDA was used to score and rank seven mitigation options, including Full Floodplain Retreat, which was not selected as the preferred option. CBA and ROI were then used to analyze the preferred diking option and to support a DMAF funding application. The study found an ROI of 7.1 for the plan as a whole.
Canadian National Research Council (NRC) *CBA, MCDA, CEA*	The NRC report 'Guidelines on undertaking a comprehensive analysis of benefits, costs and uncertainties of storm drainage and flood control infrastructure in a changing climate' provides detailed, flexible guidance for communities assessing flood mitigation options. CBA, MCDA and Cost-Effectiveness Analysis (CEA) are each discussed and compared, and guidance is given on when each is most appropriate to use.
US Federal Emergency Management Agency (FEMA) *CBA*	In the USA, community and state-led mitigation projects, including Managed Retreat, qualify for FEMA funding, which requires a CBA to demonstrate cost effectiveness. FEMA provides useful guidance and tools to help communities complete CBAs. These tools and guidelines help complete the CBAs required to access funding, but can limit program flexibility.

Other Managed Retreat Examples

Gatineau, QC: More than 250 homes were purchased and demolished following flooding in 2017 and 2019. This program is notable for its cap on compensation set at $250,000 per property.

High River, AB: A series of buyouts over several years occurred in High River following flooding in 2013.

New York, NY: Following Hurricane Sandy in 2012, NY purchased 723 properties for demolition and an additional 566 for more resilient re-development.

Christchurch, NZ: 8,000+ properties were acquired and demolished following earthquakes in 2010 & 2011.

New Orleans, LA: Buyouts were one of many tools used by FEMA as part of the Hurricane Katrina recovery program in 2005.

Lessons and Good Practices for Managed Retreat Decision-Making

Importance of Community: Community collaboration should be part of all stages of the decision-making process, including designing the process itself.

Decision Aid: CBA results are not being used in isolation to select the preferred option. Instead, CBA is being used in combination with MCDA and other decision-making processes that consider wider values and community support/input.

Maturing Practice: Methods for estimating flood damage prevented by Managed Retreat and other mitigation works are well developed, with many good examples (see Grand Forks, Merritt, Calgary, NRC)

Clarity of Purpose: Explicit and clear communication of the assessment's purpose and limitations (e.g., Grand Forks and Merritt ROI calculations for DMAF funding)

Multi-criteria: Good attempts are being made to consider broader, non-financial impacts of flood mitigation (e.g., Calgary's 'Triple Bottom Line', Merritt's quality of life, school disruption, etc.)

Flexibility: Municipalities and academics are exploring different variations and combination of CBA and MCDA tools to create place- and context-specific processes.

Challenges For Future Projects & Assessments

Reactive assessment: Mitigation projects and assessments are usually done post-disaster, rather than proactively.

Funding Constraints: Funding availability and assessment guidelines limit mitigation options and constrain assessments to more standard financial impacts (e.g., DMAF, FEMA).

Trade-offs: Difficult balance between providing guidance and fast implementation versus allowing flexibility and time for community involvement at the local level (e.g., DMAF, FEMA, NRC).

Non-Financial Impacts: Many important, non-financial impacts (e.g., environmental, psychological, cultural impacts) are left out of formal decision-making processes. Instead, they are omitted or considered informally and without transparency.

Limited Options: Assessments are typically done on a limited range of options, instead of exploring creative solutions.

Equity: Exposure to natural hazards, and the impacts of risk reduction projects, often disproportionately affect lower income and equity-seeking populations. Capturing and addressing these inequities in CLMR planning and decision-making will be an ongoing challenge for all parties involved.

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