Granton Coastal Park: a high-level climate adaptation and environmental cost benefit assessment

for City of Edinburgh Council (CEC)

September 2022

Final Report

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Executive Summary

National and local governments around the world, and in Scotland, are currently engaged in appraising the risks posed by climate change. At the coast, these include the prospect of enhanced erosion and flooding that will place coastal assets at increased risk. In response to this challenge, the City of Edinburgh Council (CEC) commissioned this report to help ensure that in a changing world, their approach to development along the City of Edinburgh (CoE) waterfront was informed and adaptive to the growing risks posed by coastal climate change.

The report below provides a rapid high-level assessment of the costs and benefits of different proposals for part of the Granton Waterfront Development Framework that aims to regenerate a 150-hectare area post-industrial area on the Firth of Forth in the northwest of Edinburgh, Scotland. Historically dominated by the Gasworks, the site now comprises a mix of vacant brownfield land, ageing industrial estates and derelict historic structures, along with pockets of residential and green space. Granton Waterfront is one of seven strategic sites prioritised for delivery as part of the Edinburgh and Southeast Scotland City Region Deal. Granton Waterfront regeneration will create a new coastal town, home to around 8,000 people on Edinburgh's waterfront. It will deliver around 3,500 net zero carbon homes, a primary school, a health centre, commercial and cultural space, and a new coastal park. The overall development will make a significant contribution to Edinburgh's net zero carbon city by the 2030 target.

The assessment focuses on the Granton Coastal Park and is intended to inform a business case for the Coastal Park element of the Granton Waterfront Development. It aims to provide additional information to underpin the planning decision-making processes for the currently proposed City of Edinburgh (CoE) City Plan 2030 and the Climate Change Risk Assessment. In particular, it provides an indication of the relative costs and benefits associated with the Coastal Park compared to the redevelopment of the area for housing or retaining its current commercial use. The Development Framework /Coastal Park aims to reduce the number of assets at risk of future erosion and flooding compared with the other scenarios under consideration. This report also provides CoE with an economic appraisal of the potential economic and related social/ecological benefits of choosing to adapt to coastal climate change now, through 'sea level wise' land-based planning. It helps the CoE well beyond the Granton Waterfront area, as this report and the three scenarios it considers, can also be used as part of the city's adaptation, strategic and local development planning.
Three scenarios are considered and assessed over a 50-year time horizon (2020-2070):

i. BAU (Business as Usual) – current light industrial land use and ongoing maintenance/replacement of existing coastal defences.

ii. Old Masterplan – replacement of light industrial estate with 600 private homes in the study area, protected by a high barrier wall. The coastal defence would require ongoing

maintenance and limit residents' and pedestrians' connection to the water (NB this masterplan was never determined).

iii. Development Framework– existing light industry removed and replaced with the proposed Coastal Park to act as a flood/erosion/storm buffer to the new housing planning to be build inland of the Coastal Park as part of the Development Framework. The proposed park would provide a place of amenity, improving connectivity between the city and the coast.

The assessment of costs is limited to the capital and operating costs of new or existing flood defences, as well as the financial costs of the proposed Coastal Park itself including land assembly and lease buy-back costs if existing businesses need to leave (under the Old and Development Framework scenarios). The assessment and valuation of benefits is based on existing tools and encompasses benefits relating to flood and erosion risk, amenity, carbon, health, biodiversity, and recreation.

Benefits and costs are assessed over a 50-year appraisal period from 2020 to 2070. Future costs and benefits are discounted at an initial rate of 3.5% per year to derive a present value (PV). PV benefits are compared with PV costs to determine the economic efficiency of the different scenarios.

The summary of results (Table E1) presents a strong economic case for creating the Coastal Park and adopting the Development Framework. The benefits of this scenario over 50 years are in the region of £18 million and significantly outweigh estimated costs in the region of £14.6 million. In contrast, the costs of the Old Masterplan scenario are expected to be significantly greater than those of the BAU and Development Framework scenarios. Table E1 shows the likely negative benefits arising out of the BAU and Old Masterplan scenarios, leading to a significant fall in social value in both cases. This finding is in line with recent national assessments of the costs and benefits of different coastal protection options, where realigning the coast and adaptation of assets, rather than continuing to defend the current land-sea boundary position, is anticipated to be the most cost-effective route in more rural areas in both economic and environmental terms (Turner et al. 2007).

Table E1: Summary and comparison present value (PV) of all scenarios

	BAU	**Old Masterplan**	**Development Framework**
Total PV costs (£)	6,376,745	19,350,572	14,603,453
Total PV benefits (£)	-9,666,820	-1,617,493	17,690,751
Net PV (£)	-16,043,565	-20,968,065	3,087,298
Benefit/Cost Ratio (BCR)	-1.52	-0.08	1.21

A key vision of the Development Framework is the connection of people to the coast. The majority of benefits associated with the Development Framework are associated with additional land and coastal-based recreational opportunities arising from much improved connectivity to the coast and

extended and enhanced green spaces. These will support health and amenity benefits for residents and visitors. Other benefits are associated with biodiversity, carbon sequestration, education and reduced flood and erosion risk to the existing 17 non-residential properties compared with the business-as-usual plan. It is worth highlighting that the Development Framework has substantive savings (i.e., reduced costs) from reduced flood risk compared with the Old Masterplan and Business as Usual. Figure E1 summarises all three scenarios and shows the benefits (orange bars) are highest for the Development Framework. Net present value (NPV) is positive only under the Development Framework.

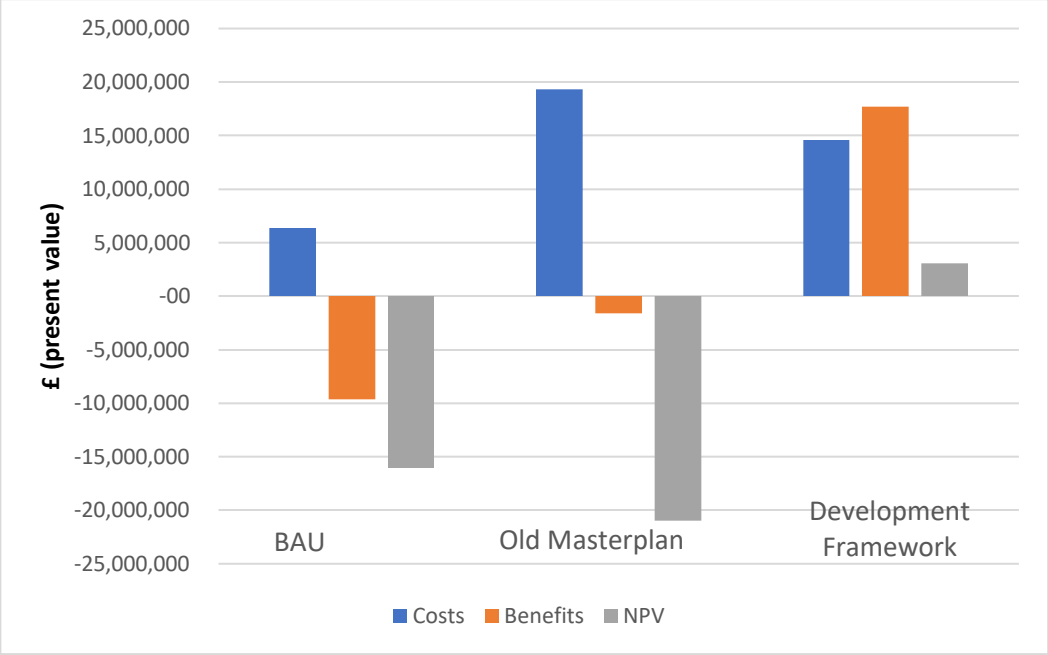

Figure E1: Summary of results

The main recommendations from this assessment are as follows.

i. The Development Framework option produces the highest benefits over the 50-year period and is the only scenario where the net present value (NPV) is positive. It is the recommended development option for this site and provides a robust underpinning for the decision-making process for approving the Development Framework. It also illustrates the potential cost benefits of adopting a coastal buffer as part of wider development planning and climate change risk assessment process for the CoE.

ii. The Coastal Park is designed to maximise benefits and minimise future costs and risks by accommodating for climate change (e.g., for the coast to adapt dynamically and migrate landwards (Rennie et al., 2021)).

iii. Consideration is given to equity and how the impacts of the Development Framework are managed in a socially and climate-just manner; an assessment of social vulnerability to erosion and flooding is recommended as part of these considerations (Dunkley et al., 2021; Sayers et al., 2017).

iv. Costs and benefits should be extended and verified through a more in-depth and longer-term analysis than undertaken here. Anticipated acceleration of future climate change risks in Scotland and associated impacts for coastal erosion and communities (Rennie et al., 2021), alongside increasing costs to design, build, maintain, and repair conventional hard coastal protection assets (Environmental Agency, 2020b) means it is highly likely that the benefits found in the next 50 years for the Development Framework will continue into the future. Further discussion of this assessment, its limitations and further recommendations are included at the end of the report.

Glossary

AAD	Annual Average Damages
BAU	Business As Usual
BCR	Benefit Cost Ratio
CBA	Cost Benefit Assessment
CEC	City of Edinburgh Council
CoE	City of Edinburgh
NPV	Net Present Value
OSMM	Ordnance Survey Master Map
PV	Present Value
SCBA	Social Cost Benefit Analysis

1. Introduction

This report has been prepared for the City of Edinburgh Council (CEC) by Environmental Policy Consulting (EPC) and the University of Glasgow (UoG) to provide a rapid high-level assessment of the costs and benefits of different proposals for the Granton Coastal Park (hereafter, Coastal Park). The assessment is intended to provide evidence to inform the business case for creating the Coastal Park as part of the Granton Waterfront Development Framework (CEC, 2021a). In particular, it provides an indication of the relative costs and benefits associated with the proposed Coastal Park compared to development of the area for housing (Old Masterplan) or maintaining its current commercial use (BAU). The Old Masterplan refers to two planning applications (03/04570/OUT and 03/04585/OUT) for mixed-use developments (residential, commercial and leisure uses) which were withdrawn before determination. This work aligns with the Scottish Government's Dynamic Coast project and utilises some key Dynamic Coast datasets (www.DynamicCoast.com). It further develops Dynamic Coast methodologies by extending analysis within urban and post-industrial shores.

Scottish planning guidance encourages the use of adaptive management approaches to managing flood (coastal, fluvial, and pluvial) and coastal erosion risk, while a recent ClimateXChange report (Hiller et al. 2019) outlines a strong case for the use of adaptive approaches as part of economic appraisals of flood risk for existing and new developments. In this context the development scenarios assessed in this report can be viewed as three different adaptation pathways. Maintaining current land use or the original proposal with 600 homes would require the use of enhanced structural measures to continue to maintain the standard of flood protection, providing the least capacity for future adaptation to climate change. In particular, adding homes in a place of future coastal flood and erosion risks may, in the future, require relocation of these assets inland. In contrast, the Coastal Park option creates space to allow the coastal edge to respond more dynamically and naturally to future climate change risks (Rennie et al., 2021); existing assets at future risk would be removed and by relocating the housing development inland would not unnecessarily lock in new development to risky sites (Payo et al., 2016; CCC, 2018). This economic appraisal can thus be used in the evaluation of the benefits of the Coastal Park (the primary aim of the report) as well as to showcase the economic impacts of different development routes/adaptation options (the secondary aim of the report).

The report is structured as follows: Section 2 provides information on the boundaries and scope of the assessment; Section 3 outlines the approach taken, including an overview of the three scenarios considered; Sections 4 and 5 provide further detail on the costs (Section 4) and benefits (Section 5) for each scenario; Section 6 includes a summary of the results, provides an indication of how different climate change scenarios may amplify the results presented here and outlines our initial conclusions; References are provided in Section 7.

1.1 Background

Granton Waterfront is a 150-hectare site on the Firth of Forth in the northwest of Edinburgh, Scotland (Figure 1). Historically dominated by the Gasworks, the site now comprises a mix of vacant brownfield land, ageing industrial estates and derelict historic structures, along with pockets of residential and green space.

Granton Waterfront is one of seven strategic sites prioritised for delivery as part of the Edinburgh and Southeast Scotland City Region Deal. In March 2018, the Council purchased the former gas works 'Forthquarter' site in Granton Waterfront and in May 2018, land in Granton Waterfront held formerly in Waterfront Edinburgh Limited (WEL/EDI) officially transferred ownership over to the Council. As a result, the Council now owns approximately 50 hectares of developable land in Granton Waterfront. In February 2020 the Planning Committee approved the Development Framework for Granton Waterfront as non-statutory planning guidance, setting out the vision and key principles for all future development.

Granton Waterfront regeneration will create a new coastal town, home to around 8,000 people on Edinburgh's waterfront. It will deliver around 3,500 net zero carbon homes, a primary school, a health centre, commercial and cultural space, and a new coastal park. These new uses will be supported by new cycling and walking routes and enhanced public transport connections. Through exemplar urban design and planning, the realisation of benefits associated with achieving a 20-minute neighbourhood with enhanced connections to the city and wider region will create a truly outstanding place to live, work, learn and visit. The overall development will make a significant contribution to Edinburgh's target to become a net zero carbon city by 2030 through a mix of energy efficient buildings, renewable energy solutions, sustainable travel options and a nature-based approach to climate mitigation and adaptation.

2. Scope

The geographical area considered below is shown in Figure 1, incorporating the area covered by the proposed Coastal Park and its coastal fringe (marked in red). It is bordered to the east and south by West Shore Road and to the west by the Gipsy Brae Recreation Ground (Figure 2A). It excludes the adjacent areas of West End Park and the proposed green network including areas to the south of West Shore Road.[1] The Development Framework's site's history includes use for a range of industrial activities (e.g. brick factory, gas works) and is now post-industrial with some vacant and derelict land and is currently predominately used for light industrial purposes (e.g. waste

[1] These areas are considered in the separate piece of work by Vivid Economics (2020) on the benefits of green space.

management, commercial and vocational educational uses) (Figure 2C-D), along with a small area of housing for the homeless and a historic walled garden on the southside of West Shore Road.

The area of the site north of West Shore Road is the area of the proposed Coastal Park, to which this report specifically refers, which was historically reclaimed from the sea, along with the recreation grounds to the west (Figure 1). This means that the land north of West Shore Road is seaward of the Mean High Water Spring (MHWS) position in the late 1800s and thus has been protected from erosion and flood risks over this period by coastal defence structures. The ground beneath this area is artificial made ground, which has a high natural underlying susceptibility to erosion (Naylor et al. 2021, Figure 3), meaning that if there were no defences, or they were not maintained/upgraded to alleviate risks as sea levels rise, the ground would naturally erode – leading to a landward retreat of the land-sea boundary.

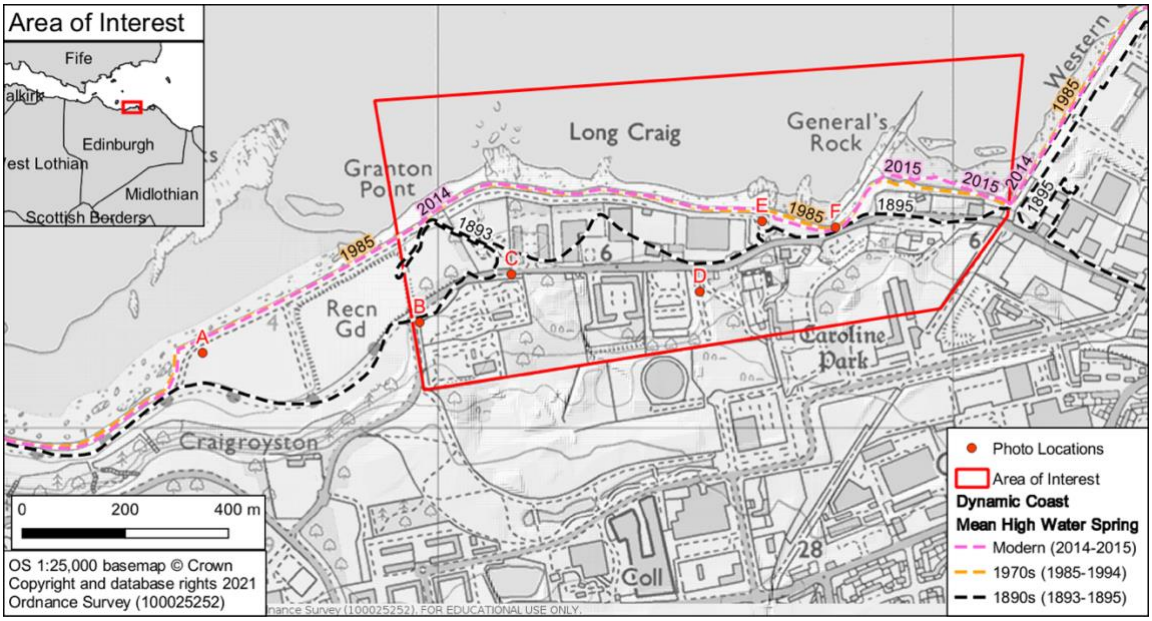

Figure 1: Assessment area- the Coastal Park area lies north/seaward of West Shore Road.

Figure 2. Current land uses and condition of the: A) amenity greenspace to the west; B and C depicting current road and pedestrian access, as well as vegetation; C and D illustrating the light industrial land use and limited view of the sea from street level; E showing the start of the cycle route which runs between the light industrial units and the coast and F showing the most natural beach between the two proposed Coastal Park areas, where land was not historically reclaimed from the sea.

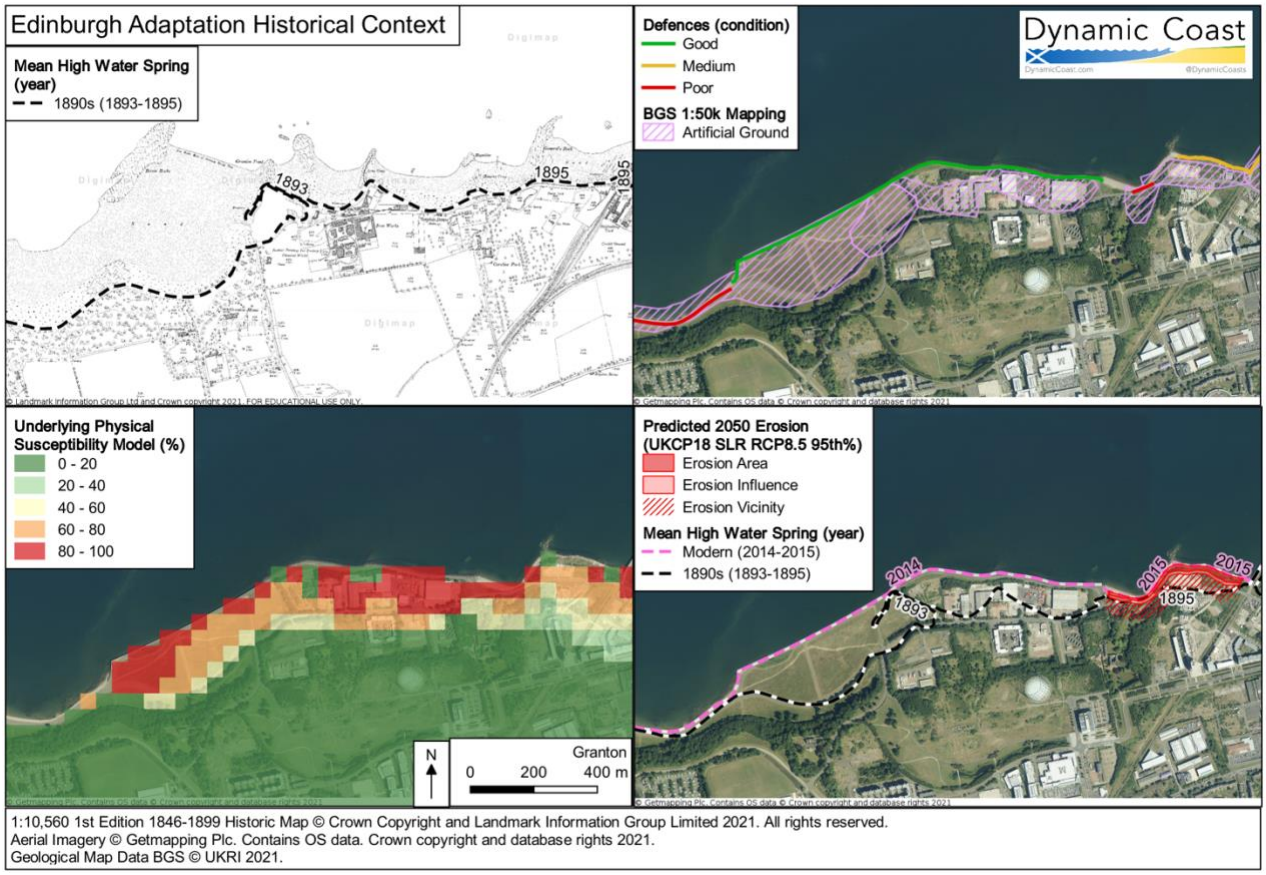

Figure 3. Extract from Dynamic Coast 2 Edinburgh Downscaling report showing historic shoreline, made ground (top right), underlying susceptibility to erosion (bottom left) and modelled future erosion (bottom right), NB. Modelling is only possible where no defence exists, all red areas on the bottom left assumed to erode in a similar manner if defences are not maintained in the future).

Given time and resource constraints, the assessment undertaken and presented here is high level, employing existing information and data, and making a number of simplifying assumptions which are clearly set out throughout this report.

We have considered and assessed the costs and benefits associated with three scenarios over the 50-year assessment period (see Section 3). These are explained in more detail below but encompass Business-As-Usual (BAU), Old Masterplan and Development Framework. Other potential scenarios are not considered. These scenarios were agreed with the CEC prior to undertaking this assessment.

The analysis undertaken and presented in this report is a Social Cost-Benefit Analysis (SCBA). This is consistent with government guidance (HM Treasury, 2020) and best practice relating to projects of this nature and means that the focus is on social and environmental costs and benefits (e.g., Willis, 2019). Economic impacts associated with the proposals (e.g., jobs, tourism, and local economic growth) are not considered in detail as part of this project, which was solely focussed on environmental and social impacts of the coastal park but could be covered in an Economic Impact Assessment of the entire development proposal.

3. Approach

3.1 Scenarios

The approach is based on an assessment of three main scenarios, including the Business-As-Usual (BAU) situation. The three scenarios are mapped and shown in Figure 4 (BAU), Figure 5 (Old Masterplan) and Figure 6 (Development Framework), where the detailed modelling of future coastal flood risks is shown in Figure 4 which applies equally to all three scenarios. Two scenarios of significant change (Old Masterplan and Development Framework) are assessed and compared to the BAU situation. Each scenario is described in Table 1. These scenarios are also illustrated in a cross-section view to illustrate how each scenario would look to an individual walking along the seafront (Figure 7).

Table 1: Scenarios considered in the assessment

Scenario	Description
BAU	Current land use (as is, assuming no redevelopment), which includes 16,020 sqm of light industrial units (e.g., workshops, storage facilities and warehouses) as well as some grass and concrete hard standings (see OSMM buildings in Figure 5). There is a modest but unattractive public walkway along the waterfront (Figure 2E), which has some visual and physical barriers, and a heavily treed and/or chain link fenced corridor with pavements along West Shore Road (Figure 2B-C). These offer limited public access to the coast; the area generally feels unsafe. There is evidence of anti-social behaviour including fly-tipping. There is a modest beach with limited access and evidence of post-industrial land use (e.g., brick beach pebbles), Figure 2F. There is also existing evidence of flooding and coastal erosion such as damage incurred during the 2010 storms (£700K in repair costs over a three-year period post-storm across the City of Edinburgh's coastal frontage, The Edinburgh Partnership, 2013), where existing defences are in poor condition and the design life of existing coastal protection assets is limited (i.e., replacement/upgrading required within the timeframe of this appraisal). Given climate change, it is highly likely that existing businesses will require property level flood risk protection in the future which may reduce their viability and/or result in enhanced future investment need through a formal flood and erosion risk alleviation scheme from CEC/Scottish Government. The current standard of much of the existing defences is poor, with asset design life limited and where ongoing maintenance (e.g., repairing concrete sea wall, beach recharge and rock/stone revetment works) and/or upgrading would be required during the appraisal period of this report. In general, the area would, under this scenario, not be seen as a destination or positive asset for those living and working in the area. Survey data from the Edinburgh Shoreline project showed that public use of this area in its current form is currently low. This is not unsurprising given the current light

	industrial use, chain-link fencing and tall, dense trees which reduce the appeal of this area for recreational uses (Figure 2B-E) This scenario would also conflict with the overall Granton Waterfront vision and is at odds with aspirations from other recent or ongoing projects in the area such the Edinburgh Living Landscapes initiative, Royal Botanic Garden's Shoreline project, Edinburgh Promenade Project, and Wardie Bay Beachwatch.
Old Masterplan	It is important to note that the planning applications for this masterplan were withdrawn and therefore never determined. The Old Masterplan consisted of an extensive private development (Figure 5) using the current line of coastal flood and erosion defence. The addition of 600 housing units (flats) would necessitate the replacement/strengthening of existing flood defences (which are generally in a poor condition) and ongoing maintenance. This would involve a new sea wall 7.9m high, resulting in a loss of visual amenity/view and a loss of connection to the water at ground level. This scenario includes limited amenity space but does include some aesthetic improvements such as landscaping and planting that would only benefit those living in the new homes and would not benefit the wider community. The new properties would remain in a flood and wave overtopping zone, that is also at risk of erosion if the shoreline is allowed to erode naturally (i.e., if defences were not maintained). There is no Coastal Park but around 1,550 sqm of commercial development (mainly retail) would be accommodated. As for BAU, future investment is likely to be needed through a formal flood scheme from CEC/Scottish Government. This option would conflict with two of Edinburgh Adapts Adaptation Action Plan Actions (BE18 and BE19) but allow them to meet Action FL14 (continue to maintain coastal defences). This option would limit the ability of the CEC to show progress on climate change adaptation (Edinburgh Adapts, 2016, pg. 21), notably, "*identify ways to adapt our changing coast and live with increased coastal flood and erosion risk*." It also conflicts with the new draft National Planning Framework (Scottish Government, 2021), "*Proposals should not result in the need for further coastal protection measures, taking into account future sea level change or increase the risk to people of coastal flooding or coastal erosion*," page 111.
Development Framework	Includes proposed Coastal Park that will act as a flood/erosion/storm buffer as well as a place of amenity, improving connectivity between the city and the coast (Figure 6). The Coastal Park would align with the CEC's environmental policy for waterside developments (Env 29) (CEC, 2021b). This policy requires development proposals to uphold 4 conditions for support: a. provide an attractive frontage to the adjacent water's edge and have had regard for character of the existing local area, b. where appropriate maintain, provide, or improve public access to and along the water's edge, c. maintain and enhance the green blue network, particularly the water environment and its nature conservation and landscape interest (inclusive of its margins and river valley) including incorporating a buffer zone along the water's edge, and d. promote the recreational use of the water. The Coastal Park would be in public ownership and be designed to be inclusive, open, and accessible to all, enhance biodiversity and provide low impact leisure and recreational opportunities. This would be achieved through a soft, landscaped climate resistant 'buffer zone' between new development and water (rather than new or upgraded engineered concrete sea walls/rock armour units) to protect assets further inland against storm, sea level rise and wave impacts in a sustainable and adaptable manner where the Coastal Park acts as a buffer. No houses would be built in the project area, but we assume that higher densities further inland would mean a net loss of around 500 housing units. We further assume that around 1,100 sqm of commercial premises would be included in the Coastal Park, such as low impact leisure and recreational activities as well as small commercial developments (e.g., cafes, bars, restaurants), which would further enhance this area as a destination and shared space. We have assumed that this commercial space could be designed in an adaptable manner, such as the use of temporary

	developments which are demountable and can be moved inland as climate change risks increase, thereby reducing the risk of these assets from future flood and erosion events. This scenario would align well with the CoE 2030 Climate Strategy: Delivering a Net Zero, Climate Resilient Edinburgh, revised CoE City Plan (CoE, 2021) and coastal section of the Scottish Government's draft National Planning Framework (Scottish Government, 2021) and provide a concrete example of how the CoE is delivering climate resilient development.

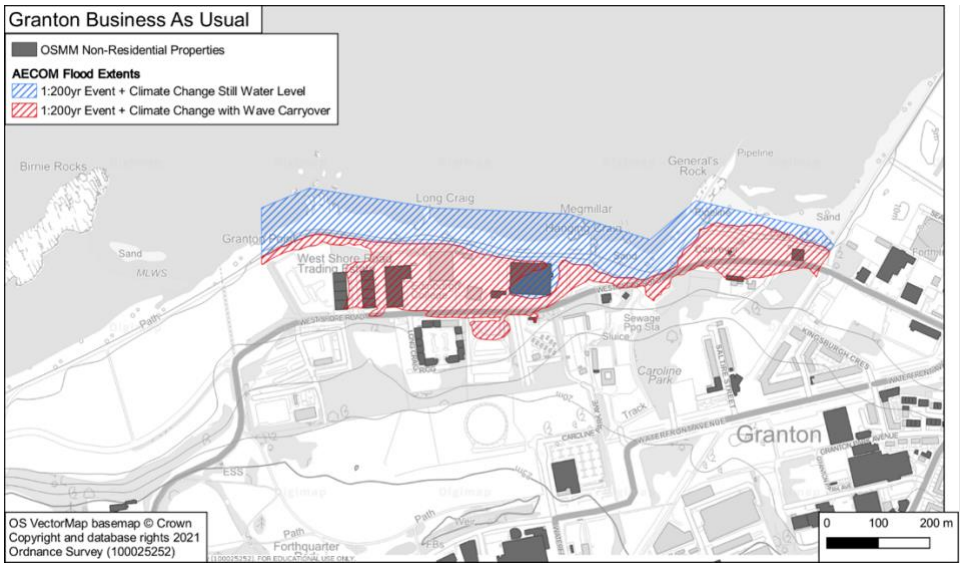

Figure 4: BAU scenario, including areas of modelled flood risk (1 in 200-year event with climate change, still and wave overtopping versions) that applies to all three scenarios (Source of flood extents: Aecom, 2019).

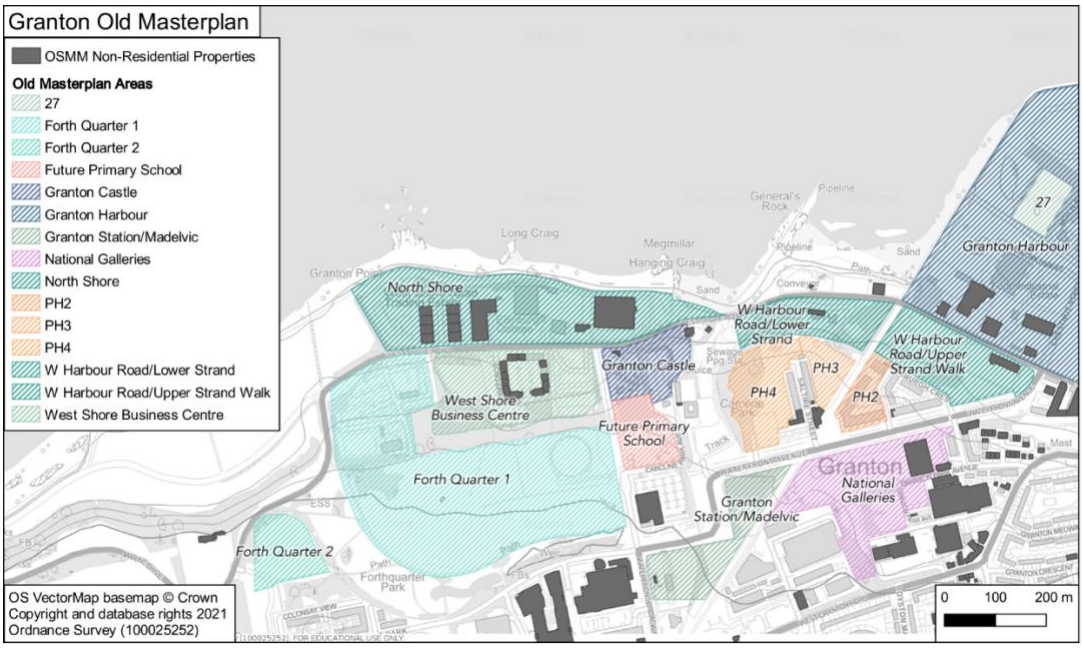

Figure 5: Old Masterplan scenario.

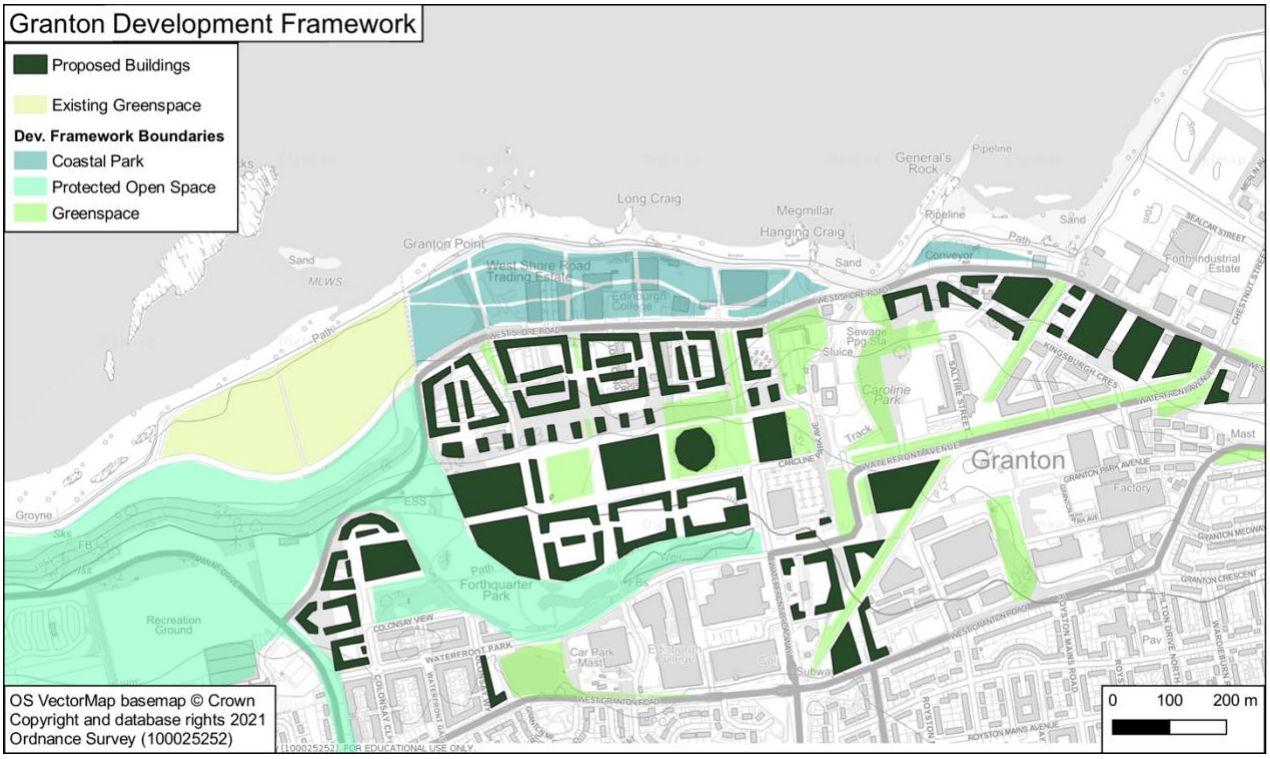

Figure 6: Development Framework scenario showing adjacent existing and planned greenspace, as well as protected open space.

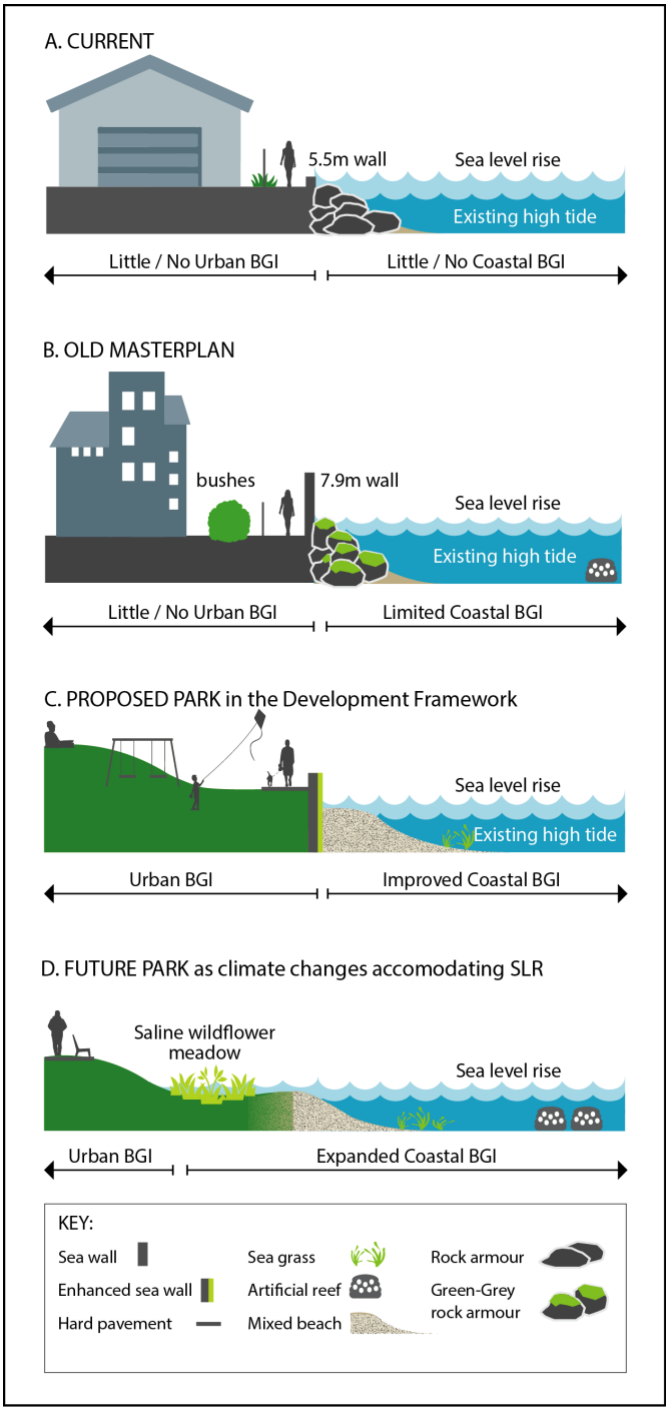

Figure 7A-D. Cross-section illustrations visualising what each scenario (A: Current = BAU, B: Old Masterplan, C: Development Framework) would look like for a pedestrian using the space, including how the proposed coastal park in the Development Framework could accommodate future climate change (D).

3.2 Methods

The assessment of costs is limited to the capital and operating costs of new or existing flood defences, as well as the financial costs of the proposed Coastal Park itself and lease buy-back costs if existing businesses need to leave (under the Old and Development Framework scenarios). We, therefore, do not consider other costs in this assessment, including repair of existing defences and loss of land due to erosion if the area is not protected or if defences fail. The cost estimates are based on existing engineering reports and on generic cost information applied to estimated quantities. Further details are provided in Section 4.

The assessment and valuation of benefits is based on B£ST (Benefits Estimation Tool – Valuing the Benefits of Blue Green Infrastructure) (CIRIA, 2019). This is one of the only widely used tools currently available (and is free to use) that supports the valuation of a comprehensive range of benefits of schemes of this type. It seeks to quantify and, where possible, monetise the benefits provided by blue and green space across a range of categories, including amenity, carbon, health, biodiversity, and recreation. It is supplemented by existing work carried out to date, primarily a recent flood risk study (WSP, 2018).

Benefits and costs are assessed over the appraisal period, which we assume to start in 2020 and end in 2070. Impacts outside of this timeframe (e.g., future erosion or future replacement of sea wall) are therefore not explicitly considered but are noted in Section 6.4. In line with government guidance (HM Treasury, 2020), future costs and benefits are discounted at a rate of 3.5% per year (declining to 3% after 30 years) to derive a present value (PV). PV benefits are compared with PV costs to determine the economic efficiency of the different scenarios. The two decision criteria presented are Benefit Cost Ratio (BCR) and Net Present Value (NPV).[2]

4. Assessment of costs

4.1 BAU

The costs of this scenario relate to the maintenance and replacement (as required) of the existing defences, including the rebuilding of the seawall to accommodate additional height up to 7.98m, to protect the area from storms, flooding and sea level rise (Figure 8), as well as the continuation of the wall from the promenade to link with the Granton Harbour wall, as set out in the 2019 Granton options appraisal report (AECOM, 2019). This would involve significant rebuilding costs. The total length of the area of interest is approximately 1.3km. This encompasses different capital cost items,

[2] BCR is a relative indicator (benefits *divided by* costs), whilst NPV is an absolute indicator (benefits *minus* costs).

as shown in Table 2. Estimates of quantity are primarily based on Arup (2016) and cost estimates are taken from Environment Agency (2015) and Defra (2021).

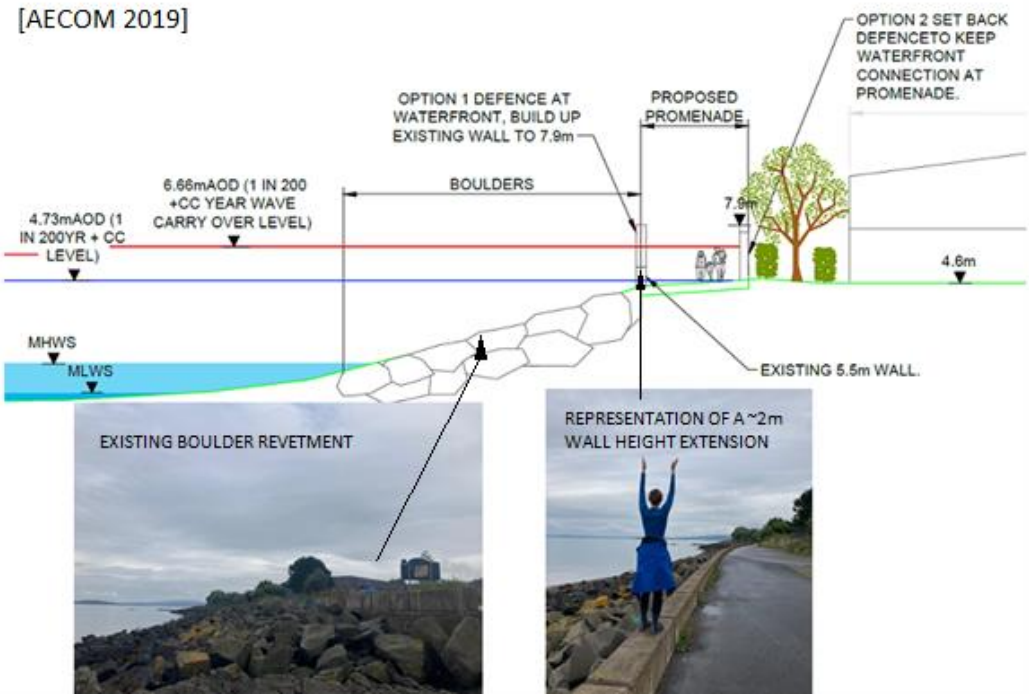

Figure 8: Cross-sectional view of coastal park displaying defences set either at waterfront or set back from waterfront, with photographs illustrating the scale of a 2-metre seawall extension (Source of diagram: Aecom 2019).

Table 2: Capital costs for BAU scenario

Cost item	Condition (existing)	Quantity	Unit cost (£)	Total cost
Raising and replacing concrete retaining seawall	Good	5,135m^2 (650m x 7.9m)	2,116/m (Defra, 2021)	10,865,660
Beach recharge	Poor	299m	2,945	880,555
Gravel recycling/re-profiling	Medium	4,318m3	1	4,318
Boulder Revetment (Rock/stone revetment works)	N/A	688m	2,280	1,568,640
Total				13,319,173

We assume that asset replacement is undertaken midway through the assessment period (i.e., 2045). Discounting this to PV terms (see Section 3.2) results in a capital cost of £5.64 million. Operational maintenance costs are assumed to be £30K per year. This is an estimate based on information provided by CEC and is likely to be an underestimate of the actual amount required, as pre-austerity

spending was somewhat higher than this. However, the assumption around operational maintenance costs is applied consistently to all three scenarios, so there is no impact on the results and conclusions. Over the assessment period, the PV of this is £741K. The total PV cost of the BAU scenario is therefore £6.38 million. Repair costs following storm events are not included separately here but maybe (at least partly) included under general maintenance and again would impact all scenarios. Although storm repair costs are uncertain and variable, as highlighted in Table 1, the costs of the 2010 event across the whole city were in the region of £700K.

4.2 Old Masterplan

The costs of this scenario are the same as those under BAU. However, we assume that asset replacement is undertaken earlier in the assessment period to protect or facilitate the housing development (2030). Discounting these costs to PV terms results in a capital cost of £9.44 million. Operational costs are assumed to be £36K per year (20% higher than the BAU scenario). Over the assessment period, the PV of this is £889K. The total PV cost of the BAU scenario is therefore £10.33 million. In addition, the cost of buying back leases/land assembly is estimated to be £10 million and is assumed to be a one-off capital cost occurring in 2023. This gives a total PV cost of £19.35 million.

4.3 Development Framework

The costs of this scenario are related to the creation of the Coastal Park and associated improvement works to the coastal defences (e.g., a new promenade). The capital cost is estimated at £5.75 million (based on discussions with CEC and costs prepared by Arcadis for CEC). We assume these include the costs of removing the existing wall and will be incurred in 2025. We further assume an annual operational cost of £30K (i.e., the same as the BAU scenario). Under this scenario, damages and disruption from storms are reduced (see Section 5 for further detail).

Discounting these costs to PV terms in line with the approach set out in Section 3.2 results in a capital cost of £4.84 million and an operational cost of £741K. The total PV cost of the Development Framework scenario is therefore £5.58 million.

As for the Old Masterplan, we include the additional cost of buying back leases/land assembly, estimated to be £10 million. This is assumed to be a one-off capital cost occurring in 2023. This gives a total PV cost of £14.60 million.

5. Assessment of benefits

5.1 Screening

The Edinburgh shoreline community mapping project effectively illustrated many of the current issues affecting the project area. It is clearly a location that has value for nearby residents. For example, Wardie Bay beach is used by locals, mainly for dog-walking, recreational sitting, or children's play. There is also some limited seal spotting, angling, and swimming. However, there are clearly frustrations with the current condition, quality, and accessibility (some areas are fenced off), and there are ideas and aspirations for improving the area, many of which would potentially be delivered by the Development Framework.

All three scenarios have been initially screened to identify the benefits of likely relevance (based on the benefit categories included in B£ST). The results of this are shown in Table 3, where 'Y' indicates the impact in that category is taken forward for further assessment. The key points are:

i. The assessment of benefits is in relation to the existing situation. Therefore, the BAU scenario does not deliver any additional benefits as it does not improve the existing situation. At best, it maintains the status quo and, in relation to levels of flood risk, the situation is likely to deteriorate (i.e., generating a negative benefit, or cost), although the evidence available to assess this is limited.

ii. To avoid the risk of double counting, care is needed where benefits occur in more than one category. This is especially true for the amenity, health, recreation, and water quality benefit categories, and is discussed further in CIRIA (2019). For this reason, we have assumed that amenity benefits will occur under the Old Masterplan scenario (associated with the 600 additional homes) and that recreation benefits will occur under the Development Framework scenario (associated with additional recreational trips by nearby residents and visitors). No health benefits are assumed here, minimising any double counting with amenity/recreation.

iii. The benefits associated with the Old Masterplan are amenity (visual and aesthetic benefits associated with 600 new homes), biodiversity and ecology (from new habitat areas), carbon sequestration (from new planting and trees), reduced crime (reduced likelihood of crime and anti-social behaviour), enabling development (economic growth associated with new homes and commercial opportunities) and flood and erosion risk management (note that the flood and erosion risk benefits are negative, i.e. the risk is likely to increase in this scenario due to the addition of homes).

iv. The benefits associated with the Development Framework are biodiversity and ecology (from new habitat areas), carbon sequestration (from new planting and trees), reduced crime (reduced likelihood of crime and anti-social behaviour), education (enhanced opportunities for local children through educational visits that increase engagement and understanding

about habitat types, natural drainage systems and coastal defences), enabling development (economic growth associated with new commercial opportunities), reducing risks of flooding and erosion (avoided costs and other benefits from reduced flood and erosion risk to assets) and recreation (new opportunities for nearby residents and visitors, and improved connectivity to the coast). It also provides accommodation space for the coast to respond dynamically to climate change risks – i.e., by allowing the coast to migrate inland as climate change accelerates (e.g., Figure 7D), by making space for coastal habitats within the Coastal Park.

v. Other benefits (where no 'Y' is indicated) are insignificant or not considered relevant. For example, whilst green infrastructure associated with urban parks can improve air quality, there are currently no known air quality issues in the area and the project site is not covered by an Air Quality Management Area (AQMA), so this potential benefit was expected to be minimal and thus not included.

Table 3: Results of screening

B£ST category	B£ST sub-category	Scenarios			Comment
		BAU	Old Masterplan	Development Framework	
Air quality		-	-	-	No air quality issues
Amenity		-	Y	*	Only relevant where new homes planned, of benefit for new and existing communities. *
Asset performance	Pumping	-	-	-	No significant impacts on wastewater assets expected
	Treating wastewater	-	-	-	
Biodiversity and ecology		-	Y	Y	Terrestrial and coastal habitat areas improved or created
Building temperature		-	-	-	No significant impacts because of scheme
Carbon sequestration		-	Y	Y	New planting and trees
Crime		-	Y	Y	Reduced likelihood of crime and anti-social behaviour
Economic growth		-	-	-	Not considered in this assessment, but could be benefits, e.g., jobs and training opportunities
Education		-	-	Y	Park enhances opportunities for local children
Enabling development		-	Y	Y	New commercial opportunities
Flooding & erosion		-	Y	Y	Change in risk of coastal flooding and/or erosion
Health	Physical activity	-	-	-	

	Emotional well-being	-	-	-	Omitted to reduce risk of double counting, see recreation
Noise		-	-	-	No impacts expected
Recreation		-	-	Y	Coastal Park creates new opportunities for nearby residents and visitors
Tourism		-	-	-	Not considered in this assessment but could be benefits, e.g., from tram extension
Traffic calming		-	-	-	No impacts expected
Water quality		-	-	-	No impacts expected
Water quantity	Flows in watercourse	-	-	-	No impacts expected
	Groundwater recharge	-	-	-	No impacts expected
	Rainwater harvesting	-	-	-	No impacts expected

**The coastal park is an amenity for all residents, but for the purposes of this assessment, it is not valued in the Development Framework due to significant overlap with the recreation category and therefore the high risk if double-counting and overestimation.*

5.2 BAU

No significant benefits are expected under this scenario, as there are no improvements to the current situation. However, it is likely that flood and erosion risks will increase as a result of climate change, leading to negative outcomes.

We estimate flood and erosion risk (based on modelling undertaken by Aecom, 2019 combined with OS MasterMap Topography Layer data[3]) to be that 17 non-residential properties are at increased risk of flood risk, largely due to storm surges and wave overtopping. This increased risk occurs until the seawall is replaced at some time in the future.

The value is based on annual average damage estimates using the Multi-Coloured Manual (FHRC, 2021). Using a 1:200 return period, a mean depth of flooding of 25cm and an average of 900m^2 per non-residential property, gives an annual estimated damage of £19,431 and a PV benefit over the assessment period of -£339,683.

There is also an increased risk of coastal erosion under this scenario. However, we have included an allowance for costs to maintain defences (Section 4.1), which should minimise this risk, at least once the seawall is replaced (assumed in 2045, later than for the Development Framework scenario). Should defences need to be strengthened earlier or further (because of climate change) and/or

[3] https://www.ordnancesurvey.co.uk/business-government/products/mastermap-topography

businesses need to relocate because of increased erosion, then additional costs would be incurred. This is discussed further in Section 6.4.

In addition, we estimate that, until 2045, 651m of West Shore Road is at risk of coastal flooding under this scenario because of wave overtopping in a 1 in 200-year event (Figure 9). Information provided by Atkins to CEC indicates annual average damages (AAD) of £3,751 for 2.4m of road flooded. Over the estimated 651m stretch of road, this gives an additional AAD for flood risk to roads of -£1,016,079. Attaching a confidence score of 75% to both the length impacted and the AAD gives a PV benefit over the assessment period (up to 2045) of -£9,327,137.

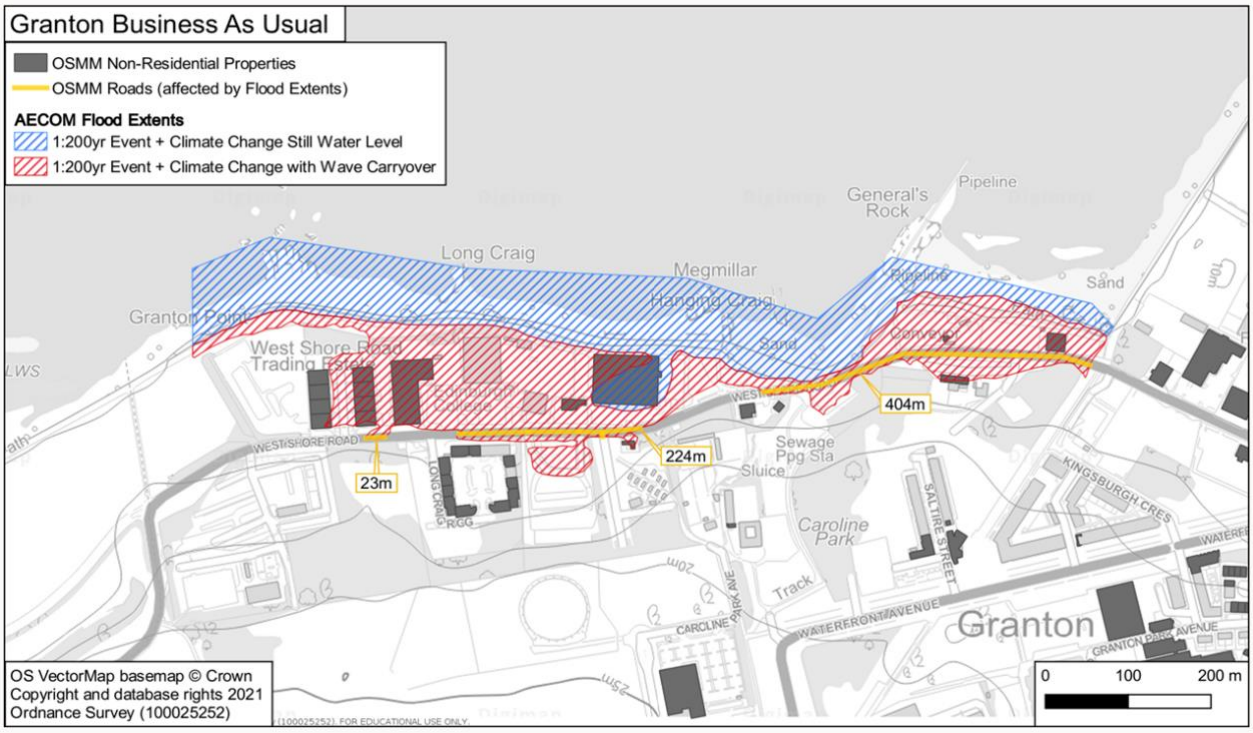

Figure 9: Flood risks to roads in BAU scenario

5.3 Old Masterplan

5.3.1 Amenity

This scenario involves some aesthetic improvements (including to the coast) and a limited amount of new greening, which will provide some amenity benefits but only to those living in the upper floors of the new homes as the public will be unable to see or access the coastline due to the height of the coastal defence,

We use B£ST to estimate the benefit in this category using the proxy measure of property price premium for these properties. The relevant improvement in B£ST relates to 'public open green space enhancement' and we assume that all 600 properties will be within 450 metres of the park.

We use an average property price for flats in the EH5 postcode area of £190,356[4] and, in line with B£ST guidance, apply 100% confidence score to the quantity and 75% score to the monetary value. This results in a one-off PV benefit of **£3,758,342**.

This is likely to overestimate benefits in this category if the enhanced flood defences that are required in this scenario (including 8m high sea wall, Figure 7) introduce detrimental impact, visually and physically blocking corridors to the coast to residents and passers-by. Whilst there is insufficient detail in the design of the Old Masterplan to be able to value this impact with any certainty, it is likely to be significant if this aspect of coastal amenity is lost. In addition, the beach may be susceptible to increased erosion risk under this scenario, further reducing amenity value. However, we have allowed for beach recharge in the cost estimate, so this risk should be minimised but to achieve this, costs would increase.

5.3.2 Biodiversity and ecology

Existing habitats and biodiversity in the area have limited specific value. Whilst the grass areas and hedgerows contain valuable forage plants (e.g., clovers, Achillea), these are generally abundant and not restricted to the project area. Currently, the area has approximately 2,925 m^2 of poor-quality grassland and 2,925 m^2 of poor-quality hedgerows. Under this scenario, this is expected to increase to 11,701 m^2 of high-quality grassland and 11,701 m^2 of good quality hedgerows, shrubs, and street trees. Over the 50-year assessment period and using 75% confidence level for both quantity and monetary values, this results in a PV benefit in this category of **£432** for improved grassland and **£1,392** for improved hedgerows.

Moreover, the redevelopment site borders the Firth of Forth which is both a Site of Special Scientific Interest (SSSI) and a Special Protection Area (SPA) (UK9004411), due to the area's value regarding the protection of internationally and nationally wintering and migratory birds (Woodward et al. 2015).

In addition, the maintenance of structural measures (e.g., seawalls) for flood protection would reduce the capacity of natural coastal habitats (and associated amenity) to respond to climate change. This means that either beach and rocky shore habitats would be lost as sea level rises, due to beach steepening and coastal squeeze, respectively. To address this and retain the biodiversity/amenity value of the beaches, beach nourishment would be required which would entail an additional cost (see Section 4.2). Ecological enhancement of any hard structural measures, by greening the grey, could provide rocky shore habitat as part of structural engineering works. Whilst this would introduce an additional cost associated with flood defences, it would also result in some

[4] Zoopla estimate (29 September 2020)

biodiversity and/or amenity benefit and cost-benefit ratios are typically very good for little additional cost (Naylor et al. 2017). However, there is insufficient detail related to the design of the Old Masterplan to be able to value this impact with any certainty. It is worth noting, however, that the Granton Waterfront Development Report (Aecom, 2019) encourages consideration of these measures during the detailed design phase of the redevelopment.

5.3.3 Carbon sequestration

This scenario is associated with a limited increase in hedgerows & shrubs, and street trees, which will have some impact on the amount of carbon sequestered. The BAU case has 2,925m^2 of hedgerows, approximately 10% of which are trees. Assuming one tree per 10m^2, this is 29 trees. By contrast, the Old Masterplan scenario has 11,701m^2 of hedgerows, approximately 10% of which are trees. Assuming one tree per 10m^2, this is 117 trees, an increase of 88 trees, all of which we assume to be of medium size. Over the 50-year assessment period and using a 50% confidence level for quantity and 100% for monetary values (based on B£ST guidance), this results in 131 tonnes of carbon sequestered and gives a PV benefit in this category of **£4,763**.

5.3.4 Crime

Given the lack of robust evidence in linking infrastructure improvements to reductions in crime, B£ST recommends that this benefit is assessed in qualitative terms only. Based on a 'medium' impact in terms of crime reduction and a 'small' size of area or number of people impacted and using a 75% confidence score for the estimation method, the scenario results in a negligible/little impact in this category.

5.3.5 Enabling development

This benefit category in B£ST is primarily associated with the creation of more 'headroom' in the drainage network, or with the role of blue green infrastructure in reducing downstream flood risk. In addition, there are currently no monetary values to support assessment in this category. For these reasons, the use of B£ST is not appropriate for the assessment of any benefits related to the enabling of development. Further, the financial benefits arising from the construction of 600 homes in this scenario will accrue largely to the developer, i.e., a private benefit. As stated in Section 2, these are not the main focus of this project, and would be better considered in an Economic Impact Assessment or similar. Benefits accruing to the residents will be largely picked up in the 'amenity' category.

5.3.6 Flood and erosion risk

We estimate (based on modelling undertaken by Aecom, 2019 combined with OS MasterMap Topography Layer data[5]) that 49 non-residential properties and 120 residential properties (those located on the ground floor) are at increased risk of flood risk, largely because of storm surges and wave overtopping. This increased risk occurs until the seawall asset is replaced in 2030. The value is based on annual average damage estimates using the Multi-Coloured Manual (FHRC, 2021). Using a 1:200 return period, a mean depth of flooding of 25cm and an average of 900m^2 per non-residential property, this gives an annual estimated damage of £65,750 and a PV benefit over the assessment period (up to 2030) of -£362,614.

In addition, we can estimate the likely mental health impacts of flood risk on residents, based on Environment Agency (2020a). This suggests that the mental health costs from flooding are in the region of £1,878 per household (flooding up to 30cm) to £4,136 (flooding above 1m) per flood event. Applying the lower value to a 1:200 return period gives £9.39 per household per year. Applying this to 600 households gives an annual estimated damage of £5,634 and a PV benefit until 2030 (when seawall is replaced) of -£49,000.

There is also an increased risk of coastal erosion under this scenario. However, we have included an allowance for costs to improve/maintain defences (Section 4.2), which should minimise this risk, at least once the seawall is replaced (assumed in 2030). When defences need to be strengthened further (because of climate change) and/or businesses need to relocate because of increased erosion during this appraisal period, then additional costs would be incurred. This is discussed further in Section 6.4. Under this scenario, these defences would need to be maintained ad infinitum throughout the life of the housing assets added – I.e., well beyond this appraisal period – so the costs identified in Section 4.2 and the flood impacts identified here reflect only those during the appraisal period rather than these additional future costs. 651m of West Shore Road is at risk of coastal flooding under this scenario as a result of wave overtopping during a 1 in 200-year event. Using the same approach as previously, the PV benefit over the assessment period (up to 2030) is -£4,970,808.

5.4 Development Framework

5.4.1 Biodiversity and ecology

Currently, the area has approximately 2,925 m^2 of poor-quality grassland and 2,925 m^2 of poor-quality hedgerows. Under this scenario, this is expected to increase to 58,505 m^2 of high-quality grassland and 58,505 m^2 of high-quality wildflower meadows, hedgerows, shrubs, and street trees.

[5] https://www.ordnancesurvey.co.uk/business-government/products/mastermap-topography

Over the 50-year assessment period and using 75% confidence level for both quantity and monetary values, this results in a PV benefit in this category of **£2,737** for improved grassland and **£8,813** for improved hedgerows.

There may be additional biodiversity and ecology benefits associated with marine ecology, as a result of making more space (over time) for more natural habitats in the tidal zone and for spray zone species. The creation or enhancement of marine ecosystems is likely to support birds and other species that thrive in beach, saltmarsh, or dune environments species (such as those at Cramond to the west). Whilst there is insufficient detail of the design of the Development Framework to be able to value this impact with any certainty, it is likely that some of these benefits are reflected in the recreation category below, as improved ecology is likely to be one of the reasons for people visiting the area for recreation.

5.4.2 Carbon sequestration

This scenario is associated with a significant increase in the area of hedgerows, shrubs, and street trees, which will have some impact on the amount of carbon sequestered. The BAU case has 2,925m^2 of hedgerows, approximately 10% of which is trees. Assuming one tree per 10m^2, this is 29 trees. By contrast, the Development Framework scenario has 58,505m^2 of hedgerows, approximately 10% of which is trees. Assuming one tree per 10m^2, this is 1,463 trees, an increase of 1,434 trees, all of which we assume to be of medium size. Over the 50-year assessment period and using 50% confidence level for quantity and 100% for monetary values (based on B£ST guidance), this results in 2,128 tonnes of carbon sequestered and gives a PV benefit in this category of **£77,615**.

5.4.3 Crime

Given the lack of robust evidence in linking infrastructure improvements to reductions in crime, B£ST recommends that this benefit is assessed in qualitative terms only. Based on a 'high' impact in terms of crime reduction and a 'small' size of area or number of people impacted and using a 75% confidence score for the estimation method, the scenario results in a little/medium impact.

5.4.4 Education

The Development Framework could present significant educational potential for a variety of groups, mainly children. Although there are currently no educational establishments within the project area, a new school is planned as part of the wider Granton redevelopment, and it is expected that this scenario would result in educational trips to the area that would not otherwise have taken place. These could be to explore and learn about the new habitat areas or the role of flood defences in protecting coastal areas leading to increased engagement and understanding of Sustainable Drainage Systems (SuDS) and Natural Flood Management (NFM). There are several schools in the

immediate vicinity, including Craigroyston Community High School (around 600 pupils), Granton Primary School (around 500 pupils), Forthview Primary School (around 400 pupils), Wardie Primary School (around 500 pupils) and St David's RC Primary School (around 400 pupils).

We estimate that 500 pupils each year will each make 1 additional visit to the area under this scenario. Over the 50-year assessment period and using 50% confidence levels for both quantity and for monetary values (based on B£ST guidance), this gives a PV benefit in this category of **£61,925**.

Additionally, events, open days, and educational visits and talks could increase overall community engagement and education.

5.4.5 Enabling development

This benefit is not assessed for the same reasons as those set out in Section 5.2.

5.4.6 Flood and erosion risk

Under this scenario, flood risk for the existing 17 non-residential properties would be eliminated. Using the same assumptions as previously, this gives an *avoided* annual estimated damage of £19,431 and a PV benefit over the assessment period of £479,801.

There is also a reduced risk of coastal erosion under this scenario, leading to 'savings' from not having to relocate properties, and not having to recharge the beach as much as an area of the park would effectively become a coastal habitat. Conversely, there would be costs associated with having to dismantle the existing defences to allow the coast to roll landward. This is discussed further in Section 6.4.

Figure 10 shows a landscape architect's vision for the Coastal Park. The Coastal Park within the Development Framework could increase long term resilience and avoid additional costs from storms by accommodating flooding and erosion (i.e., retreat of the current shoreline edge). Figure 11 compares an alternative 'softer' seaward promenade gravel path from the City of Vancouver (left) with the 1970s redevelopment which was a hard edge (right). This left-hand design was built for the 2010 Olympics and provides a more natural edge and adaptable design. To achieve these benefits with the Coastal Park in Edinburgh, the most coastal climate change resilient park design could be created at the outset, to minimise future relocation of any services and key active travel corridors through the park, with less expensive paths nearer the shoreline edge that can more readily roll landwards as sea levels rise.

Figure 10: Landscape architects sketch of Granton (Source: Collective Architecture and City of Edinburgh)

Figure 11: Alternative softer promenade (compared with hard edge) from Vancouver, Canada where the Left image (c. early 2000s development) has a much more organic and adaptable (as sea level rises) land-sea boundary with space to move the path landwards compared to the Right (c. 1980s) where saltmarsh plants in the hard engineered seawall appear as weeds and there is little or no accommodation space on land.

As for the Old Masterplan scenario, 651m of West Shore Road is at risk of coastal flooding under this scenario as a result of wave over wash during a 1 in 200-year event (Aecom, 2019). Once the park is completed (we have assumed by 2026), this risk would be mitigated via the natural buffer/landscaping, as well as hard defences in appropriate locations. Using the same approach as previously, the PV benefit over the assessment period (up to 2026) is -£3,376,554.

5.4.7 Recreation

The Development Framework is likely to result in a significant increase in recreational use within the Coastal Park, as a result of the much-improved connectivity to the coast and the extended and enhanced green spaces and associated amenities (e.g., cafes), which will be good quality and accessible. It is expected that the park will draw people primarily from the immediate area, but also from further afield.

We estimate that the scenario will result in 842,997 additional recreation trips per year. This is based on visitor numbers to comparable areas. For example, The Helix in Falkirk had an estimated 850,000 visitors in 2019/19, whilst Lochore Meadows in Fife had 835,994 visitors in 2018. These were both brownfield sites, with an ex-industrial theme that have been transformed into attractive

green spaces encompassing public art and water theme. They are comparable to the level of vision and investment that is associated with this scenario. Our figure for recreational visits is the average from these two sites. Over the 50-year assessment period and using 50% confidence levels for both quantity and for monetary values (based on B£ST guidance), this gives a present value benefit in this category of **£20,436,414.**

We consider this to a realistic estimate of the potential benefits in this category. For example, there were 153mn day trips across Scotland in 2018, with a total associated spend of £5.5bn. This equates to an average spend per day trip of £35.95, which provides a proxy for the benefits from recreational visits. Applying this value to our estimate of annual visits gives a value of around £30mn, comparable to, if somewhat higher than, the estimate derived using B£ST.

6. Results and conclusions

6.1 Costs

The estimated costs of the three scenarios are shown in Table 4. See Section 4 for further detail.

Table 4: Costs of scenarios (present values over 50-year assessment period)

Scenario	Cost (£ million)	Source and explanation
BAU	6.38	Relates to the maintenance and replacement (in 2045) of the existing defences.
Old Masterplan	19.35	Relates to the replacement (in 2025) and ongoing maintenance of flood defences to protect against coastal erosion and flooding, as well as land assembly and lease but-back costs.
Development Framework	14.60	Relates to the creation of the Coastal Park and associated improvement works to the coastal defences, as well as land assembly and lease buy-back costs.

6.2 Benefits

The distribution of monetised benefits across the different categories for each scenario is shown in Figure 11.

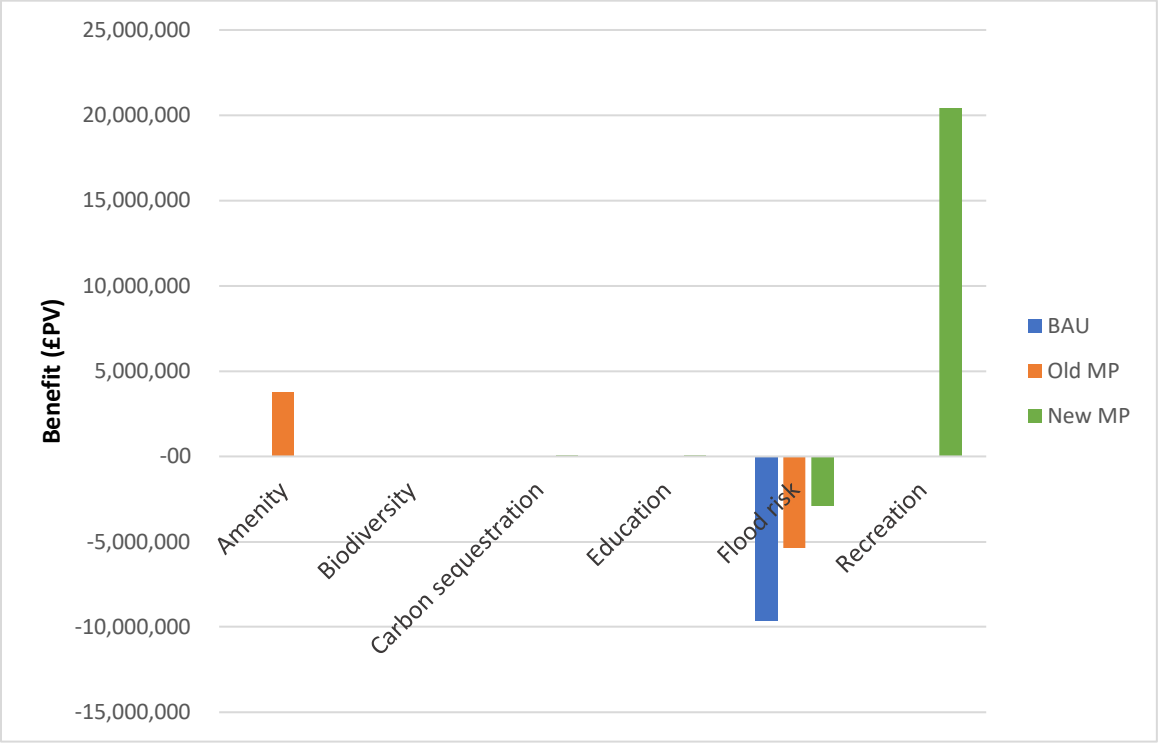

Figure 11: Distribution of benefits

6.3 Comparison of costs and benefits

The costs can be combined with the aggregated benefits to provide an estimate of the BCR and NPV for each scenario, as shown in Table 5.

Table 5: Summary and comparison of all scenarios

	BAU	Old Masterplan	Development Framework
Total PV costs (£)	6,376,745	19,350,572	14,603,453
Total PV benefits (£)	-9,666,820	-1,617,493	17,690,751
NPV (£)	-16,043,565	-20,968,065	3,087,298
BCR	-1.52	-0.08	1.21

Figure 12 shows a summary comparing all three scenarios This shows that the benefits (orange bars) are highest for the Development Framework and that the NPV (grey bars) is positive only under this scenario.

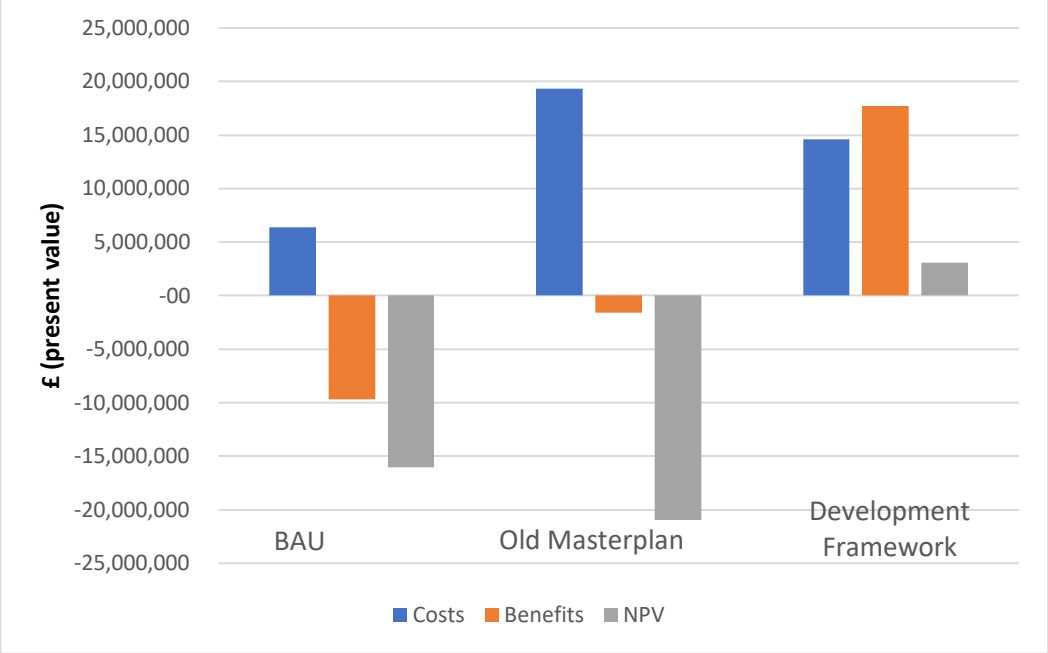

Figure 12: Summary of results

6.4 Climate change risks

Climate change risks and impacts within and beyond the appraisal period can be broadly grouped into four types of events and responses: a) change in flood event frequency, b) impacts of increased frequency and intensity of storms c) the need to relocate or demolish assets due to erosion damage, and d) beach loss.

6.4.1 Estimating the costs of increased flood frequency (on all scenarios)

The assessment above uses 1:200 flood risk calculations, the current SEPA standard flood frequency levels used for new developments and regeneration projects in Scotland. However, climate change is likely to increase the return frequency of current events, leading to a shortening of risk forecasts. For example, under a High Emissions Scenario (RCP8.5 95%), Dynamic Coast anticipates a current 1:100-year event (1% chance of happening in any given year) will become a 1:50-year event (2% annual chance). The timing of when a future 1:100yr event becomes a 1:50 year event can also be estimated using the height differences expected between the current 1:200, 1:100 and 1:50 events and deducting the sea level rise expected to occur before then. For example, under a High Emissions Scenario (RCP8.5 95%) by the mid-2030s, 15cms of sea level rise is anticipated to occur at Edinburgh, this equating to the current 1:200-year event then becoming a 1:50-year event (a 2% annual chance of occurrence).

Given the possibility of higher frequency events, it is essential to highlight that the appraisal above may underestimate the flood and erosion risk impacts within the 50-year appraisal period.

For the BAU and Old Masterplan scenarios, managing climate change risk and retaining the development north of West Shore Road would require conventional hard engineering approaches, such as those detailed in Table 2. The additional impacts of expected climate changes may mean increased maintenance of these assets is needed under these scenarios. For the Development Framework, some of these risks could be managed through landscaping of the Coastal Park (apart from the road running along the beach edge), which could reduce the costs of alleviating these risks (as raised earth bunds in the park could limit inundation of the road behind it and positioning of more expensive, multi-activity paths on bunds to reduce risk of damage during storms and/or relocation inland as erosion leads the seaward edge of the park to be transformed into a beach). Detailed modelling would be needed to assess this potential and compare costs with the BAU and the Old Masterplan scenarios. Ideally, a fourth scenario should be explored, which would be a Development Framework version that would seek to realign West Shore Road immediately as part of the current re-development to better future-proof access, as well as services lying beneath the road.

In short, the Development Framework scenario examined here is likely to be significantly more resilient to the impacts of climate change in terms of flood risks to people and assets than the BAU or Old Masterplan scenarios. It also allows for much more accommodation space (Rennie et al. 2021) for the park to be adapted as the sea level rises in the future (Figure 7D).

6.4.2 Storm Event Damage

The most recent storm event was in 2010 and caused damage to the seawalls and promenades behind, including along the Granton Waterfront area. This cost ~£700K over a three-year period to repair, disrupting active travel corridors. The proposed Coastal Park has 2.7 km of coast, which is ~ 6.3% of the city's coastal edge. Using 2010 repair costs, we estimate a minimum of £44K per large storm event to repair modest damages to coastal flood alleviation and recreation infrastructure at the water's edge. As storm intensity and/or frequency increases, it is expected that the damage will also increase.

The BAU and Old Masterplan would require continued repairs to coastal assets and disruption to recreation and active travel corridors. Whereas for the Development Framework, there may be costs of dismantling existing coastal assets that are damaged in a safe manner as well as potential re-landscaping of the edge of the Coastal Park, but these costs would likely be lower than for repeated repairs to coastal defence assets and hard surfaced recreation assets such as promenades. If key paths in the Coastal Park are situated on raised ground landward of the coastal edge, the risk of

disruption from storms to active travel corridors and recreation access could be minimised. Further work on storm damage costs and impacts is required to generate a fuller picture of these costs/benefits.

Recent work (Environment Agency, 2020b) suggests that climate change could lead to a significant uplift in asset maintenance costs, particularly in coastal areas. This is driven by the increase in sea levels (which are constant and not solely event-driven) and the continual exposure to much larger waves that will impact those assets. The cost uplift factors range from 2.0 – 4.9 (mean 3.9) for coastal maintenance and 5.0 – 8.4 (mean 7.1) for repair. This is a significant future expected cost of maintaining and repairing coastal protection assets like sea walls. For example, if the storm damages to the City of Edinburgh's defences from 2010 of £700K were increased by a factor of 5, this would increase to £3.5M in repair costs.

In short, the costs for the BAU and Old Masterplan scenarios, in particular, are likely to be significant underestimates once the impact of climate change on storm events is considered.

6.4.3 Demolition and Relocation

For the BAU and Development Framework options, there is a risk that demolition and relocation of existing built assets would be required. Under the Old Masterplan, new assets (homes) may need to be relocated as climate change impacts increase. We have not considered these costs in this assessment. Still, we would note that if climate change leads to an acceleration in erosion and existing or planned defences are unable to cope, the costs of relocating assets would be greatest for BAU and the Old Masterplan.

6.4.4. Beach loss

Beach steepening is expected to increase as sea level rises, and reductions in sediment supply (i.e., without beach recharge) will lower beach profiles (Naylor et al. 2021). Without the capacity for the beach to roll landwards and/or have an increased sediment supply from erosion of the surrounding coast (or via recharge inputs), this will lead to a narrowing of the local beach (e.g., Figure 2F). This will further reduce the currently limited flood and erosion alleviation benefits afforded by the beaches at present, as well as further reduce the biodiversity, amenity, and recreation value of these beaches.

Whilst these values have not been included in this high-level assessment, it is worth noting that for the BAU and Old Masterplan scenarios, the beach risks would be more significant than for the Development Framework, as the flood alleviation infrastructure would limit the capacity of the beaches to respond dynamically to climate change, sediment would be less available and increased

recharging would be required. Conversely, the Development Framework creates potential space for the coast to erode with time, providing sediment for beaches (where the made ground is suitable for this purpose) and, most importantly, creating space for the beach to roll landward to adapt to sea level rise, where some recharge would likely be required to maintain the beach. Beyond the life of the appraisal (after 2070), there would also be additional costs to maintain the standard of flood and erosion risk alleviation for the BAU and especially Old Masterplan scenarios. This would be required ad infinitum whilst the assets in the BAU and Old Masterplan remained in this area.

6.5 Conclusions

This assessment has shown that the proposed Coastal Park would improve the future climate resilience of the area, especially to coastal flooding and erosion risks. The creation of the Coastal Park would create a natural buffer to mitigate modelled coastal flood risks (AECOM, 2019) and the underlying natural susceptibility to erosion at this location (Naylor et al., 2021). Allowing a buffer zone to provide space for coastal processes, including climate change and erosion, is part of the emerging environmental policy for waterfront development as described in the City Plan 2030 (CEC, 2021b). The Development Framework/Coastal Park scenario also delivers on the coastal policy (Policy 35) outlined in the recently published draft National Planning Framework 4 for Scotland by considering how to adapt the coastline to future climate change and utilising nature-based solutions to permit a managed coastal change in the future (Scottish Government, 2021). This high-level assessment is a first step towards assessing the potential costs and benefits compared to the current land use and an earlier proposal of a 600-housing development on the land in question. It provides an initial indication of whether the site can be redeveloped in a climate-resilient way and constitute a proactive adaptation to coastal climate change (Brown et al., 2017; Naylor et al., 2019).

The main conclusions arising from this work are as follows:

i. Based on this assessment, there is a solid economic case for creating the Coastal Park and, thus, taking forward the Development Framework. The benefits of this scenario are considerable (expected to be in the region of £18 million over 50 years) and significantly outweigh the costs (of around £14.6 million). In contrast, the costs of the BAU and Old Masterplan scenarios are expected to outweigh the benefits significantly.

ii. Most of the benefits associated with the Development Framework are associated with additional recreational opportunities. These will support health and amenity benefits for residents and visitors. Other benefits are associated with biodiversity, carbon sequestration, education and reduced flood and erosion risk.

iii. The assessment is based on a 50-year timeframe. Considering costs and benefits beyond this period would make the economic case for the Development Framework even stronger since

this scenario is more robust to the impacts of climate change, and benefits to the area and community from the Development Framework would continue to accrue into the future. In addition, the likely uplift in future costs associated with protecting the coast under the BAU and Old Masterplan would be very significant.

iv. The Coastal Park would follow the Environmental Policy (Env 29) for Waterfront Development as outlined in the City Plan 2030 (CEC 2021b). The Park would, by design, provide an attractive front for the water's edge, provide improved public access to the water's edge, enhance the green-blue network, provide a clear buffer zone, and promote recreational use of the water. Both the BAU and Old Masterplan scenarios fail to uphold at least some of these conditions and would, therefore, not be supported.

Limitations and recommendations

The assessment presented here is at a high level only and is limited to three scenarios. In addition, the benefits assessment is limited to areas where information and data are available. There may be other scenarios and benefits to consider, e.g., water quality, health, social cohesion, and improved connectivity with nature. Further, we have identified but not monetised some benefits (e.g., crime). *We, therefore, recommend that additional plausible scenarios are considered appropriate, and that costs and benefits are verified through a more in-depth analysis than we have been able to undertake.*

Capital and operational costs are based on information provided by CEC and our estimates using published information. There is considerable uncertainty associated with costs under all three scenarios. In addition, we have not explicitly included costs for storm event repairs or loss of land due to erosion. However, repair costs may be included within general maintenance costs and likely impact all scenarios. *We recommend that additional work is undertaken to develop the cost estimates of the scenarios, considering potential capital, operational maintenance, and repair costs. This should also consider when the costs are likely to arise.*

The benefits we have assessed are estimates and are ultimately dependent on design. For example, under the Development Framework, setting back the promenade would be more resilient to future coastal storms and sea level rise impacts, helping maintain amenity benefits, lower repair/maintenance costs and design-in adaptation space for the coast to roll landward into the park area. This would make space for the boundary between land and sea to dynamically adapt to sea level and help maintain amenities like the beach with the least future costs (e.g., less beach recharge would likely be required for this option). Also, the incorporation of demountable amenities (e.g., café, playground) in the Coastal Park could increase the benefits associated with this scenario. *We,*

therefore, recommend that the Development Framework be designed in a way that is likely to maximise benefits and climate resilience simultaneously.

We have not undertaken a distributional assessment but would note that the impacts of the Development Framework will fall on different groups, including the CEC and other departments (e.g., parks, housing, health, education, transport, etc.) at local and national levels in Scotland. The socio-economic profiles and vulnerability of affected communities are not currently considered during coastal planning decision-making in Scotland (Dunkley et al., 2021). Therefore, *we recommend that consideration is given to equity and how these impacts are managed in a socially and climate-just manner.*

We have not assessed impacts on the businesses/commercial sector or the costs/benefits on other infrastructure such as water, IT, and energy networks. *We recommend that further investigation, with data licenses in place, should be undertaken to allow these aspects to be captured*.

The costs and benefits assessed in this report are limited to a 50-year timeframe. Significant costs are associated with protecting the coast in the face of future climate change impacts and the limited lifespan/adaptability of hard defences, which are outside this assessment but should be explored. As the development intends to build assets and form a community which would last beyond the 50-year appraisal period, understanding the costs and benefits of each scenario outside this timeframe would be useful. *We recommend a longer-term assessment of costs and benefits over at least 2-3 generations living in the new community – e.g., extending the assessment by over 100 years to 2200.* This would align with the City of Vancouver's (Canada) sea level rise risk assessment.

Finally, we have not considered jobs and local economic growth as this has been done as part of the site's economic component of the Environmental Impact Assessment. For example, the Development Framework has fewer housing units than the Old Masterplan. Still, it could bring more significant inward investment and provide income to the CEC from leases to new commercial premises. There would also be potential future cost savings within, and beyond the 50 years of this appraisal as the 600 houses included in the Old Masterplan would (under standard climate scenarios) not require relocation and/or demolition. A full economic and environmental appraisal such as an Economic Impact Assessment, Environmental Impact Assessment or Dynamic Adaptation Pathways appraisal could provide further insight into these costs/benefits. *We recommend that a more comprehensive assessment of all impacts is therefore conducted.*

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