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CLIMATE RESILIENCE DESIGN GUIDANCE

FLEXIBLE ADAPTATION PATHWAYS FORM

The Flexible Adaptation Pathways is one form in a series (that also includes the Site Suitability Form and Regional Coordination Form) that accompany and supplement the Climate Resilience Design Standards Tool and Climate Resilience Design Guidance. This **optional form** serves to document additional project information and encourage consideration of climate resilience in project planning and design.

A. CONTEXT

The Climate Resilience Design Standards and Guidance includes:

- **Climate Resilience Design Standards Tool**: a web-tool that provides a preliminary climate hazard exposure and risk screening and recommended climate resilience design standards for projects with physical assets within the Commonwealth of Massachusetts
- **Climate Resilience Design Guidance:** considerations, best practices, and forms to inform integration of **Climate Resilience Design Standards Tool** outputs in preliminary planning and design.

There are several forms associated with the Climate Resilience Design Guidance: Project Form, Site Suitability Form, Regional Coordination Form, and Flexible Adaptation Pathways Form. The forms are structured as follows:

Form Name	Abbreviation	Complete For…	Submission Process
Project Form	*N/A*	Project Questions: Overall Project	**Only submit** this form if the web-tool is inaccessible. Please follow instructions of your grant and other application process.
		Asset Questions: Each Asset	

Form Name	Abbreviation	Complete For…	Submission Process
Site Suitability Form	Form-SS	[Optional] Overall Project	Submit these **optional** forms as a complete package to supplement your grant application or other process.
Regional Coordination Form	Form-RC	[Optional] Overall Project	
Flexible Adaptation Pathways Form	Form-AP	[Optional] Overall Project	

B. FLEXIBLE ADAPTATION PATHWAYS FORM OVERVIEW

The Flexible Adaptation Pathways considerations are intended to encourage approaches to incorporate flexibility in project design and adaptation strategy selection. Designs should be able to function under current climate conditions as well as climate conditions through the recommended planning horizon. Where possible the design approach should embrace strategies that adapt over time and respond to changing conditions. While the case studies and best practices in this section reference different adaptation strategies, the Guidance does not provide recommendations for asset-specific adaptation strategies.

Users will still need to perform standard practices to design assets, including evaluating site conditions, asset sensitivities/thresholds and regulatory requirements. Project designs may include strategies that protect from climate hazards through the creation of permanent, temporary, or deployable infrastructure barriers to shield a site from impact or accommodate climate hazards by mitigating consequences from impacts. Adaptation strategies will be tied to site specific conditions and analyses as well as decisions made by the Asset Owner, stakeholders, Technical Staff (e.g., planners, architects, and engineers).

The Flexible Adaptation Pathways form (Form-AP) is an optional form and recommended for completion as part of the Climate Resilience Design Standards and Guidance process.

The Flexible Adaptation Pathways considerations and questions are structured into five best practices:

- ***AP-1.*** Embed future capacity and design for uncertainty
- ***AP-2.*** Design for incremental change
- ***AP-3.*** Encourage climate mitigation and other co-benefits
- ***AP-4.*** Prioritize nature-based solutions
- ***AP-5.*** Prepare for current and future operational and maintenance needs

C. FORM QUESTIONS

Provide the responses to the following questions related to the **overall project** to the best of your knowledge. The Flexible Adaptation Pathways best practices provide a framework for responding to the questions in conjunction with the project outputs of the Tool.

AP-1 Embed future capacity and design for uncertainty.

Planning and early design of physical assets should be informed by the recommended Climate Resilience Design Standards provided by the Tool, but users should consider what will happen beyond the recommended target planning horizon since climate change is still a concern beyond an asset's intended useful life. Examples of incorporating this consideration in design include over-designing a foundation that will allow flood height to be increased in the future; planning for a future pump in a lift station by designing the below ground infrastructure to accommodate the addition in the future, and/or planning land conservation for stormwater and heat mitigation strategies to be implemented in the future.

- *Example Best Practice*: City of Boston Public Works Department Climate Resilience Design Standards and Guidelines for Protection of Public Rights-of-way - PDF
- *Practice Relevance:* With the recognition of changing conditions throughout a project's intended useful life, and the abundance and importance of public rights-of-way, the City of Boston Public Works Department (BPWD) published guidelines that provide a design process for evaluating flood barriers to protect Boston's public rights-of-way. The BPWD design guidelines seek to achieve flood protection through 2070, with the option to add an additional 2 feet. of protection in the future. This was first implemented in the design of improvements at Langone Park & Puopolo Playground in Boston, MA by the Boston Parks and Recreation Department. The park is located along Boston Harbor in Boston's Historic North End. The resilience improvements on the site included raising grades and constructing a flood wall to the stillwater elevation for 2070, and the wall is designed to be able to be increased in height the future if necessary.

AP-1 QUESTIONS

AP-1.1 Will the asset still be serving its primary or secondary function at the end of its intended useful life when re-investment is needed? Click or tap here to enter text.

AP-1.2 Does your design have the ability to adapt to future climate conditions beyond what is recommended for Climate Resilience Design Standards? Please indicate how the design can be adapted and to what extent. ☐ Yes ☐ No

AP-1.2.1 Sea Level Rise/Storm Surge Click or tap here to enter text.

AP-1.2.2 Precipitation (Stormwater Flooding) Click or tap here to enter text.

AP-1.2.3 Precipitation (Riverine Flooding) Click or tap here to enter text.

AP-1.2.4 Heat Click or tap here to enter text.

AP-1.3 Is it spatially/physically feasible for below ground infrastructure (e.g., foundations, utilities, etc.) to be oversized for uncertainty? ☐ Yes ☐ No

If yes, describe. Click or tap here to enter text.

AP-2 Design for incremental change.

Designs should consider exposure and risk through an asset's useful life to identify flexible approaches to achieve the recommended Standards (return period, planning horizon, design criteria) identified through the Tool. Some projects may not be able to achieve the target design values because of various infeasibilities (e.g., technical or financial limitations), and may need to use intermediate planning horizons to achieve the Standards over time.

- *Example Best Practice*: Proposed incremental Falmouth Harbor/Main Street Adaptation Strategies, Falmouth, MA
- *Practice Relevance*: This project included a vulnerability assessment for Falmouth and proposed incremental improvements to the Route 28 Roadway. Coastal and riverine flood exposure and risk are high based on the preliminary Climate Risk Screening Output, but the risk increases through time based on review of the Massachusetts Coast Flood Risk Model (MC-FRM) maps provided through the Standards. The project team, including MassDOT, is planning an incremental adaptation approach to meet the recommended Standards, including improvements beyond the project area from Falmouth Harbor to Morse Pond. The planned incremental improvements combine grey and green infrastructure measures. Waterfront assets, including Robbins Road and the Town Lift Station, are recommended to be elevated in the immediate near term where feasible. A berm and a living shoreline are planned along Falmouth Harbor for completion by 2050. The berm will be designed to be increased in 2070 as conditions change and include hard infrastructure improvements, such as outfall protection. The roadway improvements are planned for 2070, and include designing a bridge/culvert, salt marsh, greenway, and open water connection between the Harbor and Morse Pond. The incremental approach allows the roadway to be planned and designed over time with additional nature-based benefits added to the design.

- *Example Best Practice*: Sustainable Adaptive Gradients in the Coastal Environment (SAGE) – Adaptive Gradients Framework
- *Practice Relevance:* SAGE has developed a technical report and practical guide for the Adaptive Gradients Framework, used for developing and managing infrastructure that is resilient to coastal climate hazards. The Eight Gradients of Resiliency provided by the framework include goals/requirements such as Exposure Reduction, defined as project components that "reduce the consequences of a hazardous event" on resources; and Adaptation over Time, which emphasizes evolution of design through monitoring and assessing changing climate and system functionality. This framework is emphasized for encouraging flexible, "location-appropriate, and climate adapted sustainable coastal infrastructure policy."

AP-2 QUESTIONS

AP-2.1 When is the asset anticipated to be exposed to future climate conditions?

AP-2.1.1 Sea Level Rise/Storm Surge Click or tap here to enter text.

AP-2.1.2 Other (if data are available) Click or tap here to enter text.

AP-2.2 If the climate risk changes through the asset's useful life, can the project be designed/ constructed incrementally to mitigate risk? ☐ Yes ☐ No

If yes, describe. Click or tap here to enter text.

AP-2.3 If the recommended Standards are infeasible (for example, due to landscape or budget limitations), what plans are in place to achieve the Standards over time? Click or tap here to enter text.

AP-3 Encourage climate mitigation and other co-benefits.

Projects should consider carbon mitigation in design and ways to reduce their carbon footprint and support plans for a Carbon Neutral future. Additional co-benefits increase the benefit cost ratio for a project and provide more value beyond resilience.

- *Example Case Study*: Spaulding Rehabilitation Hospital, Boston, MA
- *Case Study Relevance*: Constructed in 2013, the Spaulding Rehabilitation Hospital located in the Charlestown Navy Yard is a LEED Gold Certified building. The project resulted in the cleanup of a brownfield site. The project considered carbon mitigation and smart use of energy. The building envelope was designed to conserve energy, and includes natural daylighting, window panels and shading systems. There is an energy efficient gas-fired combined heat power and building system. The resilience investment was $1.5 million rebated with utility costs with $500k of annual cost savings.

- *Example Best Practice:* Envision Framework – Webpage
- *Practice Relevance:* Envision was established by the Institute for Sustainable Infrastructure as a framework for developing sustainable and resilient infrastructure. This framework is organized by five overarching categories, (quality of life, leadership, resource allocation, natural world, and climate & resilience), with 64 sustainability and resilience indicators or credits, to assist each category of stakeholder involved in infrastructure design and management.

AP-3 QUESTIONS

AP-3.1 How can any of the assets or the site as a whole provide other current benefits, beyond its primary use?

AP-3.1.1 Carbon Mitigation/Greenhouse Gas Reduction Click or tap here to enter text.

AP-3.1.2 Equity & Social Resilience Click or tap here to enter text.

AP-3.1.3 Economic Development Click or tap here to enter text.

AP-3.1.4 Public Health Benefits Click or tap here to enter text.

AP-3.1.5 Natural Resources/Ecosystem Services Click or tap here to enter text.

AP-3.1.6 Sustainability Click or tap here to enter text.

AP-3.2 Do these benefits change over time due to climate impacts? ☐ Yes ☐ No

If yes, identify and describe. Click or tap here to enter text.

AP-4 Prioritize nature-based solutions[1].

Natural systems and ecosystem services provide economic value and social benefit, often untapped in non-resilient projects. Nature-based solutions may cost less than traditional gray approaches through reduced upfront investment, maintenance costs, or both, and as living systems, some can become self-sustaining over time. Nature-based solutions also provide many co-benefits for the environment and society.

- *Example Best Practice*: Naturally Resilient Communities Resource Webpage
- *Practice Relevance:* Naturally Resilient Communities provides a user-friendly, visually pleasing, interactive webpage that defines related terms, link to federal resources, and identifies a wide variety of detailed technical solutions and case studies. Users can choose from several different hazard flooding and erosion type, regional location, community type, scale, and cost.

- *Example Best Practice:* Town of Brookline Climate Resilience Design Guidelines - PDF
- *Practice Relevance:* This Design Guidelines document focuses on how Low Impact Development, at the municipal level, can be used to increase resilience of new and planned development. It provides recommendations and resilience Best Management

[1] Nature-based solutions are adaptation measures focused on the protection, restoration, and/or management of ecological systems to safeguard public health, provide clean air and water, increase natural hazard resilience, and sequester carbon.

For example, a traditional engineered solution for urban flooding due to extreme precipitation may be retrofitted urban storm-water drainage systems. An alternative nature-based solution would be green roofs, bio swales, or rain gardens to filter, absorb, and manage stormwater runoff, further reducing flows into a main drainage system.

Practices for cost, maintenance, and architectural design for temperature hot spots and FEMA flood zones. It is simple to read with clear graphics and linked resources.

- *Example Best Practice:* Sustainable SITES Initiative – Webpage
- *Practice Relevance:* The SITES point-based rating system was established as a performance-based metric for sustainable and resilient land development projects. Complementary to the LEED system, SITES focuses on the project site, rather than the building/infrastructure structure. SITES evaluates how a project site maintains, supports, and/or enhances natural systems as well as the ecosystem services provided.

AP-4 QUESTIONS

AP-4.1 Are nature-based solutions being implemented on the site?

AP-4.1.1 Are nature-based solutions part of a coastal management strategy?
☐ Yes ☐ No

AP-4.1.2 Are nature-based solutions part of a stormwater management strategy?
☐ Yes ☐ No

AP-4.1.3 Are nature-based solutions part of a heat management strategy?
☐ Yes ☐ No

AP-4.2 If applicable, how are these nature-based solutions changing over time due to climate impacts? Click or tap here to enter text.

AP-4.3 If applicable, how do nature-based solutions integrate with proposed or existing hard/gray infrastructure? Click or tap here to enter text.

AP-4.4 If applicable, how do nature-based solutions integrate with regional resilience strategies? Click or tap here to enter text.

AP-5 Prepare for current and future climate resiliency operational and maintenance needs.

Operations and maintenance needs, both under current and future climate conditions, should be identified early in the design phase and communicated to the Asset Owners and Project Managers. Technical Staff should explore how those demands may impact design and Asset Owners should prepare governance structures to support maintained resilience through the project's useful life.

- *Example Best Practice*: City of Boston Public Works Department (BPWD) Climate Resilience Design Standards and Guidelines for Protection of Public Rights-of-way - PDF – Operations and Maintenance Considerations

- *Practice Relevance*: Operations and maintenance (O&M) are critical components in preparing for and adapting to climate change. Though often overlooked in the design and planning phase, thoughtful consideration has clear implications to the long-term function of assets and sustainability of budgets. The BPWD Guidelines provide a framework for estimating annual operating costs and identifying O&M needs associated with design features.

- *Example Best Practice*: National Green Infrastructure Certification Program – Webpage
- *Practice Relevance*: As the implementation and maintenance needs of green infrastructure projects continue to expand across the US, an opportunity exists to align that technical need with employment and skills training, particularly for local residents. The NGIP provides a base skill set for entry-level workers to construct, inspect and maintain green infrastructure. Thus, the program can provide multiple benefits for vulnerable neighborhoods, marginalized residents, and resource-strapped agencies. Several cities and metropolitan entities have implemented similar workforce related efforts and certificate programs, including: DC Water, Milwaukee Metropolitan Sewerage District, Montgomery County, Kansas City Water Services Department, Fairfax County, City of Baltimore Department of Public Works, Louisville Metropolitan Sewer District, San Francisco Public Utilities Commission, Pennsylvania Capital Region Water, Metropolitan Water Reclamation District of Greater Chicago, Pittsburgh Water and Sewer Authority, Metropolitan Sewer District of Greater Cincinnati, and the Boston Water and Sewer Commission.

AP-5 QUESTIONS

AP-5.1 What are the current maintenance and operational needs for the site (nature-based solutions, adaptation strategies, sustainability, etc.)? Will the extent of these needs change over time due to climate impacts? Click or tap here to enter text.

AP-5.2 Who are responsible for maintenance and operational services for the site? Does the responsible party change over time? Click or tap here to enter text.

AP-5.3 What are the current maintenance and operational costs? Do these costs increase over time due to climate impacts? Click or tap here to enter text.

AP-5.4 When are your typical repair cycles? Will frequency of maintenance change over time due to climate impacts? Click or tap here to enter text.