Stormwater Flood Reduction and Climate Resilience Capital Improvement Plan

June 2022

MVP
Municipal Vulnerability Preparedness

Belmont
MASSACHUSETTS
The Town of Homes

Weston & Sampson

EXECUTIVE SUMMARY

Weston & Sampson, on behalf of the Town of Belmont, Massachusetts, used the findings gathered throughout the MVP Planning process, informed this Stormwater Flood Reduction and Climate Resilience Capital Improvement Plan (CIP). This CIP will continue the momentum generated by the MVP Planning Process, address the high priority action items recommended by stakeholders, and help make climate resilience a primary tenant in local projects and decision making. The primary goal of this project is to understand the Town's vulnerability to flooding and climate change on a street-by-street basis using an enhanced town-wide 2-D drainage hydraulic model, and to identify and prioritize infrastructure improvements, especially in the environmental justice communities, to reduce current and future flood risks while achieving other co-benefits such as social equity, water quality and open space improvements as well as urban heat island reduction with nature-based solutions.

A 1-D model and a 2-D model were constructed, and then the model was calibrated using the flow meter data to match flow and volume within a reasonable range. The project team then calibrated the hydraulic model using the flow meter data to match flow and volume within a reasonable range. To assess current and future flood risk in the Town, the calibrated hydraulic model was run using the design storms. To assess green infrastructure benefits, potential green infrastructure locations were incorporated into the model. Model results indicate maintenance issues are the likely cause of flooding in two of the reported locations and no flooding was indicated in one of the reported flooding locations. Based on model results there is potential for flood reduction by implementing green infrastructure or capacity upgrades.

The project team used the Town's GIS database to conduct an initial assessment of the opportunities to implement nature-based solutions on public owned lands, for example the opportunities to capture runoff from large impervious areas and convert as much of that volume into infiltration loss or detention storage for slow release. Model results indicate that implementing green infrastructure can provide Town-wide flood reduction for large storms. As expected, there is a larger volume reduction percentage for smaller storms because green infrastructure projects become filled or saturated during larger events, leaving little or no capacity to capture runoff during the peak of the event. The model showed that in order to reduce flooding from conveyance restrictions, storm drain pipes will need to be upsized Town-wide, from the outfalls all the way to the upper-reaches of the drain network to realize flood reduction benefits without shifting flooding to other locations.

A Stormwater Flood Reduction and Climate Resilience Capital Improvement Plan was prepared for the Town. Section 4 of this report outlines the projects included in the Capital Improvement Plan, which are grouped into high, medium, and low priority projects. Section 4 also details the estimated costs for implementing the prioritized projects.

TABLE OF CONTENTS

LIST OF APPENDICES

ACKNOWLEDGEMENTS

Funding

This project was funded by the Executive Office of Energy and Environmental Affairs (EEA) through a Fiscal Year 2022 Municipal Vulnerability Preparedness (MVP) program grant.

Steering Committee

A special thank you to the Town staff that participated in the Steering Committee for this project, including:

- Glenn Clancy, Community Development
- Mary Trudeau, Conservation Commission
- David Blazon, Facilities-Director of Facilities
- Jay Marcotte, Public Works-DPW Director, Belmont
- Mike Santoro, Highway Division-Asst. Police Chief Town of Belmont
- Mark Hurley, Police Department-(present)
- Andrew Tobio, Fire Department-Asst. Chief and Emergency Management Director
- Wesley Chin. Belmont Health Dept.

1.0 INTRODUCTION

1.1 Background and Drivers

The Town of Belmont prepared a joint Hazard Mitigation Plan and Municipal Vulnerability Preparedness Plan (HMP-MVP Plan) as an action strategy to reduce the impacts of natural hazards and climate change within the community and the region. Extreme precipitation was among the four main hazards identified by stakeholders during Belmont's Community Resilience Building (CRB) Workshop and listening session in 2020 as part of the MVP process. Changes in precipitation can cause local issues, including flooding, damage from intense rainfall, washouts, roadway bank erosion, undercutting of critical infrastructure and utilities, and increased road pollutants in waterbodies. Stormwater flooding may result from large unplanned-for areas of hardscape, undersized culverts, and insufficient stormwater detention and drainage. Lexington Street, Belmont Street, Orchard Street off of Concord Avenue, Trapelo Road were also noted as localized areas of flooding.

The community's focus on extreme precipitation and flooding comes as no surprise. Belmont is already experiencing the impacts of climate change. Extreme rain events are becoming increasingly intense and frequent, particularly in the Northeast region of the country. Precipitation during heavy events in the Northeast increased by more than 70% between 1958 and 2010. Climate change data suggests that these trends will continue. While the average annual precipitation observed between 1971 - 2000 was 47 inches, Massachusetts could experience up to a 16% increase in annual precipitation by the end of the century.[1] Precipitation drives stormwater peak flow and volume and, therefore, stormwater infrastructure design criteria. For example, the 24-hour, 100-year storm event in 1961 was 6.5" but increased to 8.4" by 2015.[2] Therefore, stormwater infrastructure should be designed with climate change in mind, so that these systems can handle the increasing flows projected to occur throughout their design life.

Belmont's CRB Workshop participants considered risk associated with climate change while identifying local vulnerabilities and brainstorming potential adaptation action items. Many of these items were related to flooding and stormwater management. For example, aging and undersized stormwater infrastructure were identified as infrastructural vulnerabilities. High priority action items included:

- Cost-benefit analysis of flood management projects
- Model existing drainage system utilizing updated rainfall data to evaluate flooding conditions under projected climate change conditions

The Town of Belmont shared these findings as part of its virtual Public Listening Session Webinar. Residents were invited to share their feedback on climate hazards, strengths and vulnerabilities, and priority adaptation action items by participating in the meeting and completing an online survey. This public survey was advertised on the Town's website and social media platforms and received nearly 100 responses. Key findings included:

- Most respondents (36%) identified extreme precipitation as the climate hazard of most concern
- Flooding appears to have the most personal impact on the Belmont community (53 out of

[1] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA). 2020. "Changes in Precipitation." Climate Change Clearinghouse for the Commonwealth. ResilientMA.org/changes/changes-in-precipitation

[2] NOAA TP-40 (1961) and NOAA Atlas 14 Volume 10 (2015)

89 short-answer responses mentioned flood impacts)
- Most respondents (20%) identified a cost-benefit analysis of flood management projects as a high priority action item

The results of this public survey, as well as the findings gathered throughout the MVP Planning process, informed this Stormwater Flood Reduction and Climate Resilience Capital Improvement Plan (CIP). This CIP will continue the momentum generated by the MVP Planning Process, address the high priority action items recommended by stakeholders, and help make climate resilience a primary tenant in local projects and decision making. The project's main components are summarized below:
- Update the Town's existing storm drain model
- Conduct a flood risk assessment of the existing stormwater system under the current future climate conditions
- Evaluate flood mitigation options, including nature-based solutions and associated other co-benefits.
- Conduct a robust public education and engagement process to inform the project's deliverables

1.2 Goals

The primary goal of this project is to understand the Town's vulnerability to flooding and climate change on a street-by-street basis using an enhanced town-wide 2-D drainage hydraulic model, and to identify and prioritize infrastructure improvements, especially in the environmental justice communities, to reduce current and future flood risks while achieving other co-benefits such as social equity, water quality and open space improvements as well as urban heat island reduction with nature-based solutions.

Other objectives of this project include:
- Engage residents in working towards shared solutions for climate change impacts through active public outreach process.
- Address high priority action items identified during the MVP Planning Process
- Improve the existing 1-D drainage model by creating a 2-D model upgrade with an enhanced climate evaluation.
- Document current and future flooding problems in Belmont using the revised model
- Integrate Belmont's drainage model into the regional 2-D hydraulic model to evaluate both the impacts of the planned regional interventions on Belmont and Belmont's planned improvements on the regional system.
- Identify site-specific green infrastructure/nature-based controls for implementation
- Identify any needed grey stormwater infrastructure improvements
- Identify the associated co-benefits from resilience improvements to inform prioritization
- Create an action plan or road map to equitably implement the identified capital improvements

The result of this project is a comprehensive plan that will help the Town become more resilient to future flooding. The implementation of the plan will require municipal leadership, private partnership, and resident support.

2.0 TOWN-WIDE STORMWATER DRAINAGE MODEL DEVELOPMENT

Built on Belmont's existing storm drain hydraulic model, a town-wide 1-dimensional (1-D) and 2-dimensional (2-D) hydraulic model was developed to assess the flood risk through the Town. A 2-D model is required to properly evaluate the depth of flooding that is important for detailed floodplain analysis.

2.1 Data Collection

2.1.1 Field Investigation

The Town's latest GIS database for storm drains, topography, land cover as well as land use and property ownership information was collected. Available major drainage infrastructure record drawings were also collected and reviewed.

The project team performed field investigations at locations where flooding had occurred, or accuracy of drainage infrastructure is critical for modeling. The Town's existing drainage model is based on GIS. During the field investigation, dimensions of critical drainage infrastructure such as major culverts were verified, and conditions be noted. For areas that had experienced flooding, the project team will also note local drainage patterns and size/condition/number/location of catch basins. A summary memo was prepared to document the field investigation results, it is included in Appendix A.

2.1.2 Temporary Flow Metering

The Town's existing drainage model had not been calibrated with flow monitoring data. For this project, the project team performed temporary flow metering for eight weeks at eight hydraulically critical locations in the storm drains with the use of a specialty sub-contractor. A summary memo was prepared to document the temporary flow monitoring results, it is included in Appendix B.

2.2 Model Update and Integration

Based on the data collected from field investigation and temporary flow metering, the project team updated the storm drain network and developed a 1-D and 2-D hydraulic model.

2.2.1 1-D Model Build

A 1-D hydraulic model of the Town's storm drain network was built in InfoWorks ICM version 2021.2 using manhole and pipe ArcGIS data provided by the Town. Data gaps were filled using available information. Model subcatchments were created using storm drain connectivity and topography from a Digital Elevation Model (DEM), available from the State of Massachusetts on MassGIS. Manhole rim elevations were inferred from the DEM. An impervious shapefile, also from MassGIS, was used to determine the impervious percent area for each subcatchment. Town building shapefiles were used to determine the impervious roof area percentage for each subcatchment. The Town storm drain system was then integrated into a clipped version of the region-wide model built for the Mystic River flood analysis. Storage arrays were inserted to represent Clay Pit Pond and Little Pond. Where Belmont storm drains discharge to the City of Cambridge drain system, boundary conditions from region model results were established to represent backwater conditions.

2.2.2 2-D Model Build

The 2-D model utilized the storm drain network within the Town's existing drainage model and includes a 2-D mesh system that is built off the Town's surface topography to provide more accurate representation of the area and depth of flooding. The 2-D model build emulated the Mystic Regional Model with 2-D mesh element criteria, surface infiltration, roughness, and other parameters. The Town buildings were incorporated into the 2-D mesh as voids to prevent flow from traveling across building footprints. Boundary conditions were added at the edges of the 2-D mesh where Region Model results indicate flooding was observed to impact Belmont, such as at Alewife Brook and Fresh Pond.

Using the State DEM, the following creeks were added to the model as river reaches: Winns Brook south of Tyler Road; Alewife Brook through Underwood Park south of Concord Avenue; and Alewife Brook south of Flanders Road. Where bridges cross the river reaches, they were added using FEMA model data. In addition to the pond storage arrays added during the 1-D model build, bank lines were added so that pond storage area was not double-counted.

2.2.3 Model Calibration

The project team then calibrated the hydraulic model using the flow meter data to match flow and volume within a reasonable range. The model was calibrated using eight meters, strategically placed throughout the Town's drain network to calibrate the largest areas feasible with the eight meters. Although no dry weather calibration was completed for this storm system, dry weather levels in metered pipes, just upstream of outfalls, were used to set initial boundary conditions so as to not have free discharge conditions and mimic actual conditions. After dry weather initial conditions were established, the model was calibrated for wet weather. Only one wet weather event was observed during the metering period, on April 19th. The event had total rainfall of 1.02-inches, with a 15-minute peak intensity of 0.48 in/hr. Given there was only one event for calibration and that depth and flow were well matched, they were considered calibrated sufficiently for initial planning. However, further flow monitoring and calibration is recommended to better-refine the accuracy in the model and achieve higher confidence in model results. We also evaluated the RMAT Climate Design recommendations using the RMAT Tool and selected future precipitation values to run the model. A summary memo was prepared to document the 1-D and 2-D model updates and the calibration results, it is included in Appendix C.

2.3 Existing Conditions

To assess current and future flood risk in the Town, the calibrated hydraulic model was run using the design storms. Present-day storms were obtained from the Northeast Reagional Climate Center (NRCC) at Cornell University. Future storms were developed by Weston & Sampson for other climate change studies completed in the Boston area. At a meeting with Town staff, eleven areas were identified where flooding frequently occurrs. These locations were investigated and observations relating to potential causes of flooding were reported in the Field Investigation Memo submitted in December 2021 (Appendix A). Ten of the eleven locations were used to validate the model results. The eleventh location, at Mill Street and Trapelo Road is not modeled due to lack of GIS pipe information in that area. The model results show flooding in the 10-year 24-hour present design storm for seven of the ten reported flooding locations. The Field Investigation Memo reported that two of these locations' observed flooding was due to clogged catch basins. The model represents a well maintained system, which means catch basins are not clogged. The third location, where no flooding was predicted but has been observed, is at Burbank Elementary School on Sharpe Road. It is possible that more detail is needed for the school property drainage network to provide more detail and accuracy.

To assess green infrastructure benefits, potential green infrastructure locations were incorporated into the model. Flood volumes surrounding groups of closely-located green infrastructure locations were calculated using results polygons, which is a standard way of calculating flood volumes in InfoWorks

ICM to provide consistent results for comparing multiple storm events. The polygons were drawn to include surrounding area where flooding would be impacted by the project. These polygons summarize the maximum flood volume in the polygon.

The model was validated using flooding locations reported in the Field Investigation Memo, illustrating the model's accuracy. Model results indicate maintenance issues are the likely cause of flooding in two of the reported locations and no flooding was indicated in one of the reported flooding locations. It may be beneficial to incorporate further detail into the model in the one location where model results did not indicate flooding and it does not appear to be the result of a maintenance issue. Based on model results there is potential for flood reduction by implementing green infrastructure or capacity upgrades. For more information on existing conditions, please refer to the the Existing Condition Evaluation Memo in Appendix D.

2.4 Anticipating Future Conditions Due to Climate Change

This project is informed by the most up-to-date climate change science and data. During the MVP Planning process, the project team utilized the climate change data available on the ResilientMA Climate Change Clearinghouse.[3] The team will continue to refer to these data sets, particularly the data on changes in precipitation. The team will also refer to NOAA's Atlas 14 Volume 10 for precipitation frequency data. We will also draw upon the future expected precipitation amounts that are being developed by the Resilient Massachusetts Action Team (RMAT). This includes a 13% increase over the 1% NOAA Atlas precipitation numbers for the year 2070 and up to 30% for 2100. In addition, we have completed the optional RMAT Climate Resilience Design Standards Tool to help guide the precipitation values used in the model update and in site evaluations for GI.

[3] Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA). 2020. "Resilient MA: Climate Change Clearinghouse for the Commonwealth." ResilientMA.org

3.0 DEVELOPMENT AND EVALUATION OF RESILIENCY ALTERNATIVES

3.1 Alternatives Identified

3.1.1 Nature-Based Solutions

The Executive Office of Energy and Environmental Affairs (EEA) describes Nature-Based Solutions (NBS) as 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. Incorporating NBS in local planning and design projects produces long-term solutions that benefit human and natural systems. NBS can be preservation of existing natural resources (e.g., protection of open space), restoration of a natural resource (e.g., stream channel stabilization, creation of floodplain, reforestation), or construction of Green Infrastructure. Green Infrastructure (GI) is considered a climate resilience best management practice that uses surface features including native vegetation, soils and other natural processes to reduce flooding and improve water quality. These systems collect and store runoff, aiding in infiltration and treatment of stormwater, and decrease burden to the grey infrastructure system.

Not only do NBS contribute to flood mitigation, they also provide economic, social/cultural, and environmental co-benefits:

- Economic co-benefits can include increased tourism, increased property values, energy savings, generation of income, and sometimes even food and water provisions.
- Social/cultural co-benefits can include recreation, education, creation of gathering space, opportunities to add spiritual or religious or artistic value, and overall improvement to quality of life.
- Environmental co-benefits typically include temperature mitigation, regulation of the water cycle and groundwater recharge, noise mitigation, and creation of biodiversity and sources of pollination.

The project team used the Town's GIS database to conduct an initial assessment of the opportunities to implement nature-based solutions on public owned lands, for example the opportunities to capture runoff from large impervious areas and convert as much of that volume into infiltration loss or detention storage for slow release. While the green infrastructure may not be able to reduce the peak flow during the large storm events, the infiltration and detention might reduce the flood volume, thus reducing the flooding severity. Large wetlands, if feasible, could have more effect on flood reduction. More information on NBS opportunities is provided in Appendix E.

3.1.2 Green Infrastructure

Green infrastructure is one of a number of NBS. Green infrastructure is a stormwater management approach which is designed to slow down, collect, and treat stormwater where it falls. Green infrastructure offers a feasible and valuable solution for urban areas facing the challenges of climate change. It connects urban hydrological functions with vegetation systems in urban landscape design, providing overall socioeconomic benefits that are greater than the sum of its individual components. Taken together as a comprehensive system, components of green infrastructure projects strengthen urban ecosystems by employing natural processes in man-made environments. Systems of Green Infrastructure can include components like rain gardens, sunken street tree planters, permeable paving, daylighting streams, widening river flood plains, and conveyance swales.

Implemented together forming full, green streets and green areas, they can augment the stresses on existing, over-inundated, or undersized stormwater drainage in urban area by reducing and flattening the peak flow during storm events. As surface solutions, green infrastructure components can also help to reshape our urban environment by reclaiming and redesigning spaces for pedestrians. They combine the demand for sustainable water and stormwater management with the demands of adaptive urban life and planning.

3.1.3 Gray Infrastructure

Gray infrastructure generally consists of inlets, gutters, drains, and underground pipes that transport water to the nearest waterbody. Grey infrastructure may also include surface or underground storage, pumping systems, and retention ponds. Gray infrastructure is designed to reduce impacts of flooding and optimize efficiency of the system, but is not built solely from NBS, like green infrastructure.

3.1.4 Nature-Based Solutions Toolkit

Three scales of Solutions are described within this toolkit:

1) Large Footprint
2) Small Footprint
3) Single Building or Site Level
4) Non-structural for Community-Wide Implementation

<u>Large Footprint Nature-Based Stormwater Management Solutions</u>

Benefits:

- Ability to capture large volumes of stormwater leads to significant runoff volume reduction / control and groundwater recharge
- Provides downstream benefits for water bodies suffering from nutrient loading and pollution, can be used to address watershed-wide pollution budgets (Total Maximum Daily Loads or TMDLs)

Constraints:

- Changes made to large sites can impact the watershed or sub-watershed scale
- Can be applied in both urban and rural areas, both for impervious and pervious existing site conditions as it generally involves site redesign
- Generally require significant maintenance (contracted), can require specific equipment (vacuum trucks, excavators, etc.)
- Local, state, and federal environmental permitting must be considered during conceptualization

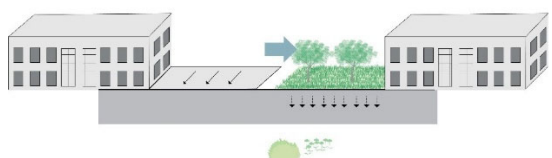
Examples:

- <u>Reforestation</u>: Reforestation or concentrated tree planting increases tree canopy, helps reduce urban heat, improves air quality, and mitigates air pollution through carbon uptake and sequestration. Reforestation can occur in empty lots, within existing parks, or interstitial spaces between roads or properties.

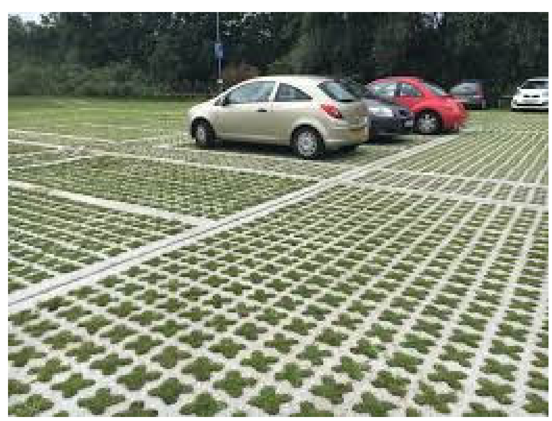
- Turf Management: Unpaved areas that are repeatedly compacted, such as dirt parking areas, can turn previously pervious soil into an impervious surface by removing the infiltration capacity of the soil. An overall increase in impervious surface within a watershed will ultimately lead to increased flooding within the watershed without proper stormwater management. A turf management plan can be utilized to promote maintenance of unpaved areas to help restore and maintain the infiltration capacity of the soil and avoid conversion to an impervious surface that would increase stormwater runoff.

- Floodable parks: Floodable parks and recreation spaces represent the greatest opportunity for large retention spaces within urban areas. They can be located throughout the watershed and receive stormwater via conveyance systems or adjacent water bodies. They can provide a combination of hydrological services including water quality improvements via retention, detention, and infiltration.

- Depaving (to vegetation): Open areas that do not need to remain paved (e.g., adjacent to buildings, parking medians, back of sidewalk, large areas of unused parking lot, removed buildings, etc.)



- Permeable Paving: Roadways and sidewalks are big contributors to stormwater runoff. Replacing impervious surfaces with permeable pavement allows for reduced runoff and infiltration back into the ground or water to enter a stormwater system. Permeable pavement can be used where stable, hard surfaces are needed along streets, sidewalks and in parking areas and can be used in conjunction with underground storage.



Small-Footprint Nature-Based Stormwater Management Solutions

Benefits:

- Ability to capture large volumes of stormwater leads to significant runoff volume reduction / control and groundwater recharge
- Provides downstream benefits for water bodies suffering from nutrient loading and pollution, can be used in tandem to address sub-watershed-wide pollution budgets (Total Maximum Daily Loads or TMDLs)

Constraints:

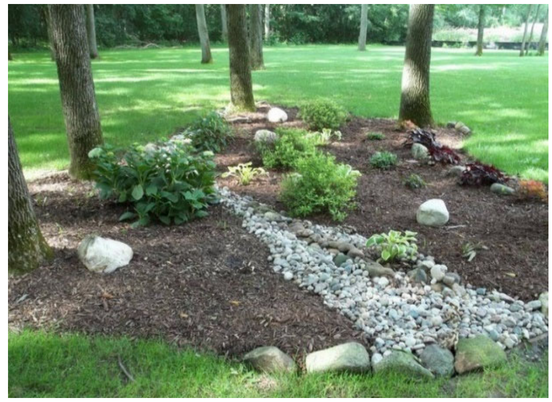
- Can be applied in both urban and rural areas, both for impervious and pervious existing site conditions
- Maintenance can be done mostly by hand or with readily-available and common equipment, manageable for town staff or residents

Examples:

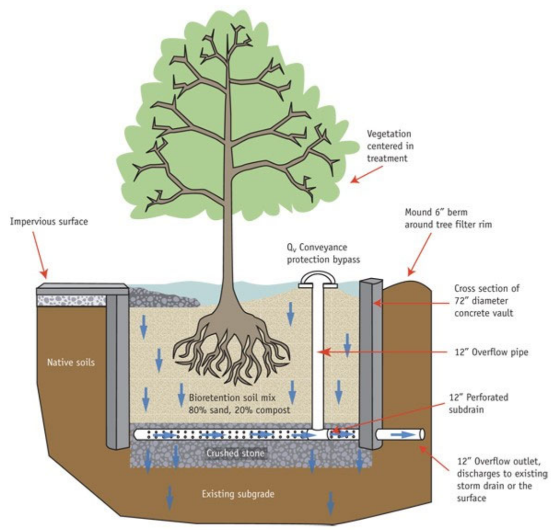
- Swales / bioswales: The primary function of swales is to intercept stormwater runoff before it enters the existing drainage system and convey runoff to other GI features. In many instances, swales can temporarily store runoff and even allow some degree of infiltration. Swales are very useful because they can fit within narrow stretches along roadways and reconnect separated surface flows.

- Bioretention: Bioretention areas capture and hold stormwater runoff and allow it to slowly infiltrate through soil media, thus reducing flooding. Roots uptake water as well as nutrients in the runoff. These systems provide water quality benefits by removing pollutants. They can be constructed as basins or linear features. They can be installed in open spaces, along sidewalks, in medians, and parking lot edges to directly treat runoff from surrounding impervious surfaces. These components can retain stormwater for future uses or detain it before it flows back into the drainage system after a storm event.

- Strategic Planting (i.e., "Rain Garden"): Building or area where planted raised berms, depressed beds, or gravel pathways can be used to guide the flow of water on the site.



- Tree box filter: A tree box filter consists of an open bottom concrete barrel filled with a porous soil media, an underdrain in crushed gravel, and a tree. Stormwater is directed from surrounding impervious surfaces through the top of the soil media. Stormwater percolates through the media to the underlying ground. Treated stormwater beyond the design capacity is directed to the underdrain where it may be directed to a storm drain, other device, or surface water discharge.



Nature-Based Stormwater Management Solutions for Homes or Small Businesses

Benefits:

- Ability to capture small volumes of stormwater leads to site-specific runoff volume reduction / control and groundwater recharge

Constraints:

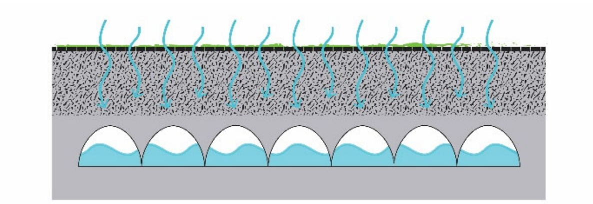
- Changes made to sites, depending on size, can impact the sub-watershed or even neighborhood scale
- Can be applied in both urban and rural areas, both for impervious and pervious existing site conditions
- Maintenance can be done mostly by hand, manageable for individual property owners

Examples:

- Disconnecting Downspouts: A building with an internal manifold that can be disconnected to either a pervious surface with a splash guard or a downspout planter.

- Rainwater harvesting: This simple practice reroutes rooftop drainage pipes from draining rainwater into the storm sewer to instead draining it into rain barrels and cisterns. You can use it to store stormwater and/or provide targeted release of stormwater to infiltrate into the soil.

In addition, while not explicitly considered a nature-based solution, underground stormwater storage is an important alternative to consider. Underground storage is designed to store large volumes of stormwater underground. Storage chambers can be used for reuse, retention, detention, or controlling the flow of on-site stormwater runoff. They can be implemented with various depths and forms (i.e., chambers, vaults). They can be coupled with a surface GI practice such that they capture overflow in excess of the designed volumes and flows for that specific practice.



<u>Non-Structural Nature-Based Stormwater Management Solutions for the Municipality</u>

Benefits:

- Can provide a combination of hydrological services including but not limited to: site-specific flood reduction, water quality improvements, groundwater recharge
- Allows for small volumes of rainwater to be captured on site
- Can improve Urban Heat Island Effect by increasing green spaces
- Provides downstream benefits for water bodies suffering from nutrient loading and pollution
- Can provide ecological habitat and lower maintenance needs by using native species where plantings are called for

Constraints:

- Changes made to sites, depending on size, can impact the sub-watershed or even neighborhood scale
- Can be applied in both urban and rural areas, both for impervious and pervious existing site conditions
- Non-maintenance solutions

Table 3-1 Non-Structural Nature-Based Solutions

Solution	Description
Green Streets Policy	Like complete streets policy, guides approach and application
Local Tree Ordinance/Bylaw	Regulate public and/or private tree canopy beyond public shade trees.
Enhanced Stormwater Management	Approach to require appropriate sites to capture and detain, infiltrate, over 1" of stormwater runoff, beyond MA stormwater handbook
Stormwater Utility/Enterprise Fund	Sustainable, equitable, manner to provide income for stormwater management, including

	flood projects. Can create incentives for individual property owners to undertake nature-based solutions on the property level
Modify Local Zoning for Climate Resilience	incentive reduction in impervious cover and preservation/reforestation of non-constructed space
Adopt a local floodplain more stringent than the FEMA 100- year flood zone	Consider regulating the 500 year flood zone or future predicted flood zone based on modeling

3.2 Flood Reduction of Resiliency Alternatives

This plan intends to incorporate climate resiliency into the CIP by looking for opportunities to implement the green infrastructure methods described above.

3.2.1 Green Infrastructure Alternatives and Associated Flood Reduction

Forty-five green infrastructure projects were provided with conceptual design information. The types of green infrastructure projects include:

- Underground storage/infiltration
- Permeable pavers
- Bioretention basins
- Bioswales

See Appendix F for the complete list of green infrastructure projects evaluated. The projects were incorporated into the model using InfoWorks ICM Sustainable Urban Drainage Systems (SUDS) parameters in the modeled subcatchments or as infiltration zones in the 2D surface mesh. Floodable parks were not added because they are already incorporated in the 2D model ground surface.

Model results indicate that implementing green infrastructure can provide Town-wide flood reduction for large storms. As expected, there is a larger volume reduction percentage for smaller storms because green infrastructure projects become filled or saturated during larger events, leaving little or no capacity to capture runoff during the peak of the event. There are projects that are in areas with no flooding and therefore are not recommended. However, if the projects are in areas where the model is not as refined, further analysis would provide more confidence in the level of flooding.

A detailed prioritization of project implementation is included in Section 4. It is important to note that the hydraulic model assumes storm drains are properly maintained and that catch basins are not clogged. While not explicitly modeled, proper drain maintenance will also reduce the risk of flooding by ensuring the drain network functions at peak performance.

3.2.2 Gray Infrastructure Alternatives and Associated Flood Reduction

Separate from the green infrastructure analysis, gray infrastructure solutions were also considered to assess flood reduction benefits. The 10-year 24-hour present design storm was used to examine the model for potential locations where upsizing pipes could reduce flooding by increasing conveyance capacity. Several locations were identified that have flooding due to lack of capacity.

The model showed that although flooding is alleviated at the certain locations, increased capacity allows more flow to travel downstream, which could increase the amount of flooding downstream. This was the case in all areas explored for pipe upsizing. Therefore, in order to reduce flooding from conveyance restrictions, storm drain pipes will need to be upsized Town-wide, from the outfalls all the way to the upper-reaches of the drain network to realize flood reduction benefits without shifting flooding to other locations. Increasing pipe sizes to provide inline storage was also considered but, given the shallow depths at which the storm pipes are located, it is not feasible to provide any meaningful amount of storage in this manner.

3.2.3 Integration into Regional Efforts

A meeting was conducted with Mystical River Watershed Association and the Charles River Wateshed Association on June 20, 2022 to present on the model integration and impacts and opportunities. This initial regional modeling effort was limited to nearer future conditions, i.e., 2030 10-year and 2030 25-year storms. The purpose of this initial evaluation was to have a preliminary understanding of the benefits of the improvements in Belmont to neighboring communities and vice versa. The regional models are constructed at a regional resolution and the Belmont model will provide more details and site-specific evaluations.

3.3 Prioritization of Solutions

To determine which green infrastructure opportunities should be prioritized for implementation, several factors were considered, the impact of the opportunity on stormwater reduction, the feasibility of implementing the opportunity, and the co-benefits of implementing the opportunity. The following equation was used to come up with the final prioritization score.

Prioritization Score (S) = Impact on Stormwater Reduction (ISR) + Co-Benefits of Implementation (CB) + Feasibility of Implementation (FI)

Indicators under each of the three categories were weighted based on their relative importance to Belmont. For example, projects which align with existing planned projects receive more weight under 'feasibility of implementation'. Definitions of each prioritization can be found below.

Impact on Stormwater Reduction – How much stormwater can be stored within the green infrastructure system based on hydraulic and hydrologic modeling that determine amount of stormwater impacts and reduction. Indicators of Impact of Stormwater that were considered include the following:

- Percent reduction of total volume during a baseline present day 2-year storm event
- Percent reduction of total volume during a 2070 2-year storm event

Co-Benefits of Implementation – the co-benefits of implementation are defined by following attributes:

- Location in an Environmental Justice (EJ) community - green infrastructure can provide benefits to populations that have historically experienced negative environmental impacts due to discriminatory practices that impact economic and housing opportunity and poorly impact health.
- Urban Heat Island (UHI) improvements - green infrastructure can contribute to the reduction of urban heat island and provide shading to the public realm. Depending on the size and type of species, the amount of urban heat island reduction varies. For example, a large tree that is planted as a component of reforestation contributes to 35-45 degree (F) of temperature reduction, while smaller shrubs also provide benefit but not as substantially.

- Contribution to placemaking – green infrastructure can create a new place for residents to enjoy or use. A project's contribution to placemaking depends on its ability to allow people to use or be within the space, such as with a park, plaza, or field.
- Foster biodiversity– green infrastructure can contribute to biodiversity by creating wildlife habitat, improve habitat quality, and enhance pollination. Depending on the vegetation variety and type, this can positively contribute to the health of the ecosystem

Feasibility of Implementation – the feasibility of implementation is defined by following attributes:
- Alignment with existing and short-term projects – whether the project coincides with an existing Town project, so the site will already be under construction, or coincides with roadways that will be under paving moratorium and unable to be altered in the near future.
- Maintenance frequency - the maintenance requirements in terms of effort of the strategy were evaluated based on a rough estimate of time of maintenance cycles.
- Maintenance effort – the effort requirements of maintaining the strategy were evaluated based on the type of equipment that must be available and the staff training/knowledge.

3.3.1 Prioritization Impact Scoring

The following tables outline the impact score definitions for the co-benefits of implementation (Table 3-2) and the feasibility of implementation (Table 3-3). The co-benefits of implementation and the feasibility of implementation were weighted to determine their effect on the Prioritization Score. The weights of the impact scores are shown in the following tables.

Table 3-2-Belmont, MA Co-Benefit of Implementation Impact Scores

Score	Environmental Justice Neighborhood	Reduction of Urban Heat	Placemaking	Biodiversity / Habitat
Weight	13%	7%	12%	9%
0	Not located in EJ Community	No lawn / vegetation	Does not create new space for residents	Provides attributes of biodiversity
1		Low vegetation / Lawn		
2		Medium vegetation / Small Shrubs		
3		Heavy vegetation / Large Shrubs	Provides greenery and co-benefits to existing space	Fulfils some attributes of biodiversity
4		Small trees		

5	Located in EJ Community	Large trees	Creates or contributes to new place to be enjoyed by residents	Fulfils all attributes of biodiversity

Table 3-2-Belmont, MA Feasibility of Implementation Impact Scores			
Score	Alignment with Existing / Short-Term Project	Maintenance Frequency	Maintenance Effort
Weight	25%	17%	17%
1	Current or near future facilities build that GI implementation would disturb	Bi-Weekly / Weekly	In-House New Equipment & Particular Staff Knowledge
2	Location under 5-year paving moratorium or roadways scheduled for Town construction in FY22 or FY23 (15-20 years)	Monthly	Contracted Work
3	Roadway with no moratorium or planned roadway work, or Town planned site construction in next 10-15 years	4x a Year	
4	Upcoming planned road work in FY24 or FY25	2x a Year	In-House Available Equipment & Particular Staff Knowledge
5	Town planned site construction in next 5 years	Annual	In-House Available Equipment & Basic Staff Knowledge

The estimated maintenance frequency and maintenance effort scoring for the different typed of green infrastructure are as shown in Table 3-3.

Table 3-3-Green Infrastructure Maintenance		
Green Infrastructure	Maintenance Frequency	Maintenance Effort
Permeable Pavement	5	2
Bioretention	2	4
Bioswale	2	5
Underground Storage	4	4
Green Streets	3	3
Floodable Parks	1	5

3.3.2 *Project Prioritization*

The final project prioritization and project prioritization scoring can be found in Appendix G.

4.0 CAPITAL IMPROVEMENT PLAN

4.1 Recommended Capital Improvement Plan and Cost

A Climate Resilience Capital Improvement Plan was prepared for the Town. The following matrix (Table 4-1) outlines the projects included in the Capital Improvement Plan, which are grouped into high, medium, and low priority projects. These groupings are based on coinciding scheduled construction projects and project prioritization as discussed in Section 3.3.

4.1.1 Basis of Cost Estimates

Conceptual-level costs were developed for all solutions identified. The Town used a unit-based costing approach that accounts for approximate cost per unit of flood storage volume and treatment volume anticipated. Non-quantifiable co-benefits such as water quality and air quality improvements were identified along with the project costs. This can be used by Belmont to rank and select projects for future implementation.

Unit pricing by square foot or cubic foot was determined for the following green infrastructure types: bioretention areas, bioswales, underground storage, permeable pavement, and green streets. A materials and labor subtotal was obtained for each green infrastructure opportunity based on this unit pricing. For floodable parks and fields, unit pricing by square foot or cubic foot was less feasible, so a materials and labor subtotal was estimated by site. Information used to obtain pricing for this OPC included MassDOT bid prices for the time period from June 2021 to June 2022 from Districts 4, 5, and 6, which generally cover middle and eastern Massachusetts; pricing from vendors; online research; and experience with other projects. The unit pricing is summarized in Table 4-3 and further discussed below.

Table 4-1 Unit Pricing

Item	Size	Cost per SF	Notes
Bioretention Areas	small	$60	Includes potential drainage pipes, curbing, paving, etc.
	medium	$50	
	large	$40	
Floodable Parks & Fields			Estimated by site
Bioswales	small	$50	Includes potential drainage pipes, curbing, paving, etc.
	medium	$40	
	large	$30	
Underground Storage		$30	Includes R-tanks, crushed stone/gravel backfill, excavation, and labor installation costs
Permeable Pavement	small	$20	Includes Ecoraster Bloxx, sand & crushed stone/gravel borrows, R&D paving, and labor installation costs
	medium	$15	
	large	$12	
Green Streets		$22	Includes bioretention basins and permeable pavement

The following costs were added to the materials and labor subtotal for each green infrastructure opportunity to obtain a total materials and installation labor cost:

- A 3% mobilization/demobilization cost
- A 20% materials & labor contingency, to account for the high variability in prices over recent years
- A 20% contingency for unknowns

The following items were added to the materials and labor cost to obtain an overall subtotal cost for each opportunity:

- Daily surveying Opinion of Probable Cost (OPC)
- Estimated permitting OPC
- Design and bidding OPC, based on experience with previous projects

A lump sum item for construction administration, based on project size, which assumes work associated with construction over one to two months related to change order requests and field directives, part-time field oversight, review & approval of pay requests, and status meetings. Finally, a 20% general contingency was applied to the overall subtotal for each opportunity to account for any unknown costs that may be incurred, considering that these opportunities are still in the very early stages of design. The range of total costs and approximate cost per type of project can be found in Table 4-2.

Table 4-2 Costs per Project

Type of Project	# Projects	Cost Range	Approx. Cost per Project
Bioretention Area	14	\$50,000 - \$900,000	\$275,000
Floodable Parks/Fields	2	\$150,000- \$375,000	\$240,000
Bioswales	9	\$50,000 - \$275,000	\$120,000
Permeable Pavement	18	\$60,000 - \$825,000	\$200,000
Underground Storage	10	\$330,000 - \$3,000,000	\$1,200,000
Green Streets	3	varies	\$2,400,000

Appendix H shows the total estimated OPC for the identified priority CIP projects described in Table 4-1. A complete cost estimate table can be viewed in Appendix H. Please note that this is an engineer's OPC. Weston & Sampson has no control over the cost of availability of labor, equipment or materials, or over market conditions or a Contractor's method of pricing. The OPC has been developed based on Weston & Sampson's professional judgement and experience. Weston & Sampson makes no guarantee that bids or negotiated cost of any work will not vary from this OPC. Costs presented are considered concept/screening level and therefore have an estimated accuracy range of -20% to +50%. Costs are presented in June 2022 dollars.

4.2 Recommendations for Next Steps

4.2.1 Funding Sources

There are a number of grant, loan, and local funding sources that may support implementation of this work:

- Already established sewer enterprise fund
- New stormwater enterprise fund
- Grants such as MVP, Section 319, Section 604(b), additional MVP Action Grants
- Clean Water State Revolving Loans

4.2.2 Operations and Maintenance

It is recommended that Belmont continue to monitor and maintain their assets. It is important to recognize that the CIP is a living document and not a finished product. Providing, at minimum, an annual update will help keep the plan a useful decision-making tool for Belmont personnel.

Additionally, all parties must be included in the operations and maintenance of this plan and the prioritized infrastructure. The Building Committee appointed for facilities projects on stormwater management, should attend educational training on NBS and this stormwater flood reduction and climate resilience CIP.

4.2.3 Procedure to Include Information in Mapping

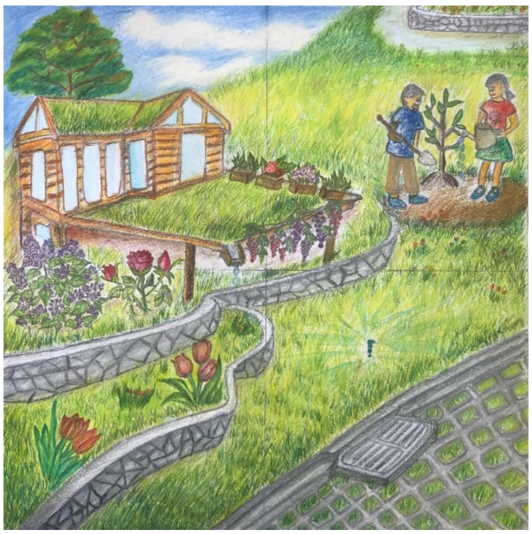
Belmont should make efforts to keep their GIS and other asset management systems up to date with the prioritized project and other NBS. By continuing to update the information in mapping, Belmont will be able to prioritize and schedule upgrades and repairs.

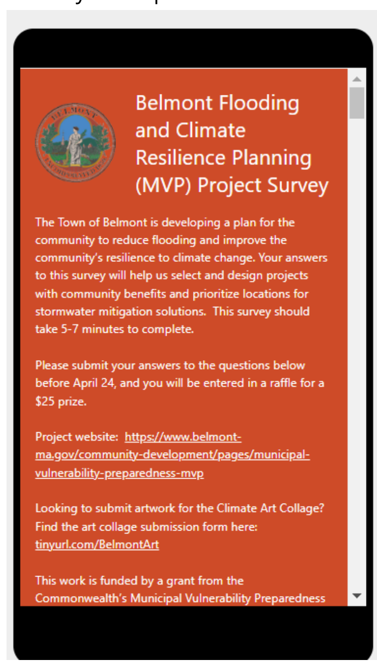
5.0 PUBLIC ENGAGEMENT

5.1 Get the Word Out & Collecting Input

We held a kickoff meeting with stakeholders to get input on project approach. Meeting materials are included in Appendix I. We launched public outreach on the overall project with a press release, website, video, and survey promoted through emailed and printed flyers, social media, and with help from local groups distributing information (in lieu of an in-person event). We offered a local prize raffle to encourage participation. Public engagement materials are included in Appendix J.

Between April 8 and May 9, 2022, 35 people participated in Belmont's Flooding and Climate Resilience Planning Project Survey and Art Collage. The winning submission for the Climate Art Collage, shown below, depicts pervious pavement, planted areas, and very little paved area.





5.1.1 Stakeholder and Public Preferences

Community members expressed general support and excitement about installation of green infrastructure projects in the project area through the survey and virtual meeting. Key findings included:

- the places where most people experienced flooding and heat overlapped with locations of green infrastructure sites planned
- people want more vegetation, trees and shade, better walking paths, and improved safety for bikes by sidewalks and streetsides (Concord Avenue was the most popular), parking lots, and at schools and parks.

Multiple people noted flooding concerns at key cross streets adjacent to Clay Pit Pond (Becket, Goden, School St.), Concord Ave., PQ Park, Beaver Brook by the playground, Fairview at School St., Brighton St. by the railroad, and School and Orchard Streets.

Survey responses and other input from community members raised other important topics, including:

- Maintenance plans for installed features
- Enhancing the Town's long-term plans and practices around urban forestry

- Native and climate-sensitive plant/tree choices

These findings were shared in project team meetings and incorporated into the design process.

During this phase, we also gathered information from the community that can inform future green infrastructure projects. Respondents shared clear preferences for more pedestrian and bike safety and connectivity, protected open space, native species that support pollinators, increasing the use of permeable asphalt, and improving bus stops. They also expressed broader concerns about reducing construction and parking lots. These preferences should be considered in designing future green infrastructure projects in Belmont.

5.2 Presenting Designs

We shared final design concepts for the stormwater projects with the steering committee. We shared the designs at a virtual meeting with local organizations and interested stakeholders, which was promoted through emailed flyers, social media, posted signs, and local email lists.

APPENDIX A

Field Investigation Memorandum

APPENDIX B

Flow Monitoring Report

APPENDIX C

Model Update, Integration, and Calibration Memorandum

APPENDIX D

Existing Condition Flooding Evaluation

APPENDIX E

Nature Based Solutions Opportunities

APPENDIX F

Flood Reduction Alternatives Assessment

APPENDIX G

Prioritization Matrix

APPENDIX H

Cost Estimate Table

APPENDIX I

Meeting Materials

APPENDIX J

Public Engagement Materials