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Stormwater Management

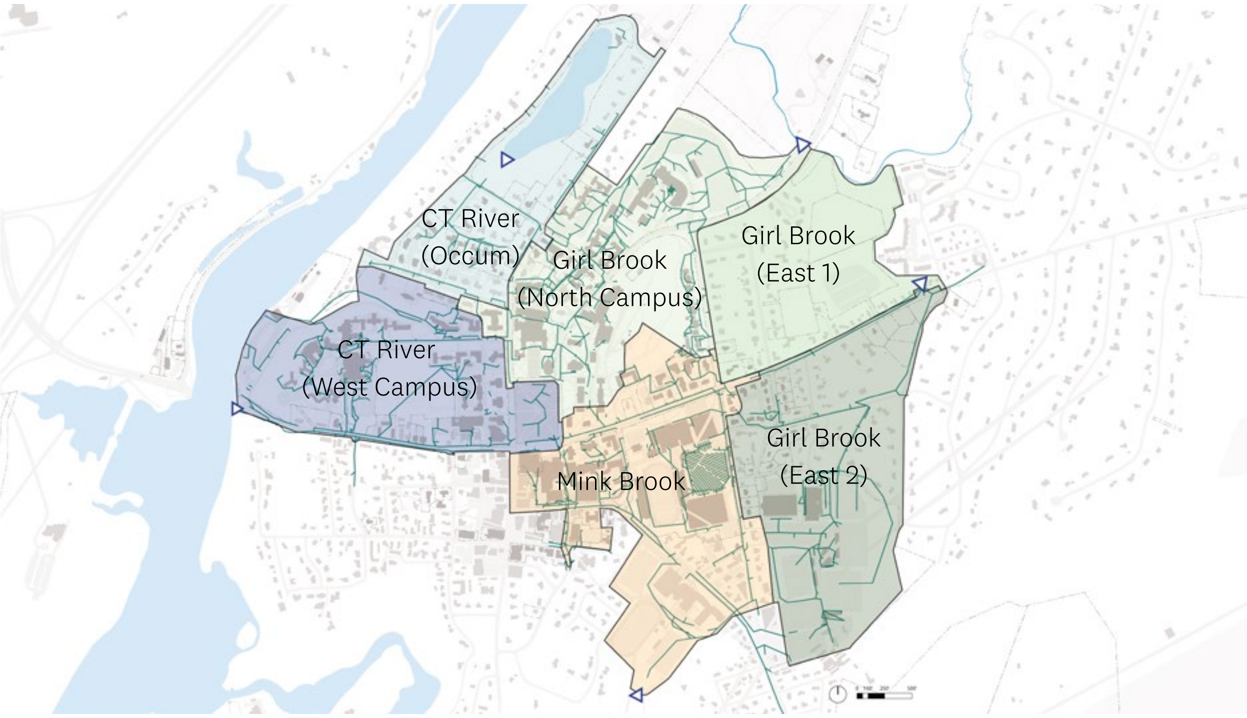
Stormwater Considerations

Existing Natural Resources

The Dartmouth College land holdings are nestled within a region of high value natural resources. Although the Hanover Campus is highly developed, several natural resources exist on the campus including Occom Pond, the Connecticut River, the headwaters of the Girl and Mink Brooks, and naturalized open space including College Park and the cemetery. The majority of other Dartmouth College land holdings including Pine Park, the Organic Farm, Oak Hill, and Mt. Moosilauke remain undeveloped in a more naturalized state.

Existing Campus Sub-Watersheds

The Hanover Campus is divided into six major sub-watersheds contributing stormwater to the Connecticut River. The western portion of campus drains to the Connecticut River either directly or via Occom Pond. The northern and eastern portions of campus drain to the Girl Brook. The southern portions of campus, primarily the athletics areas, drain in a southerly direction to Mink Brook.

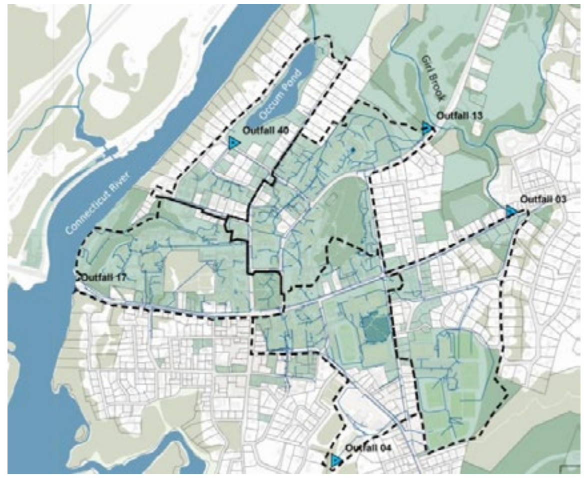


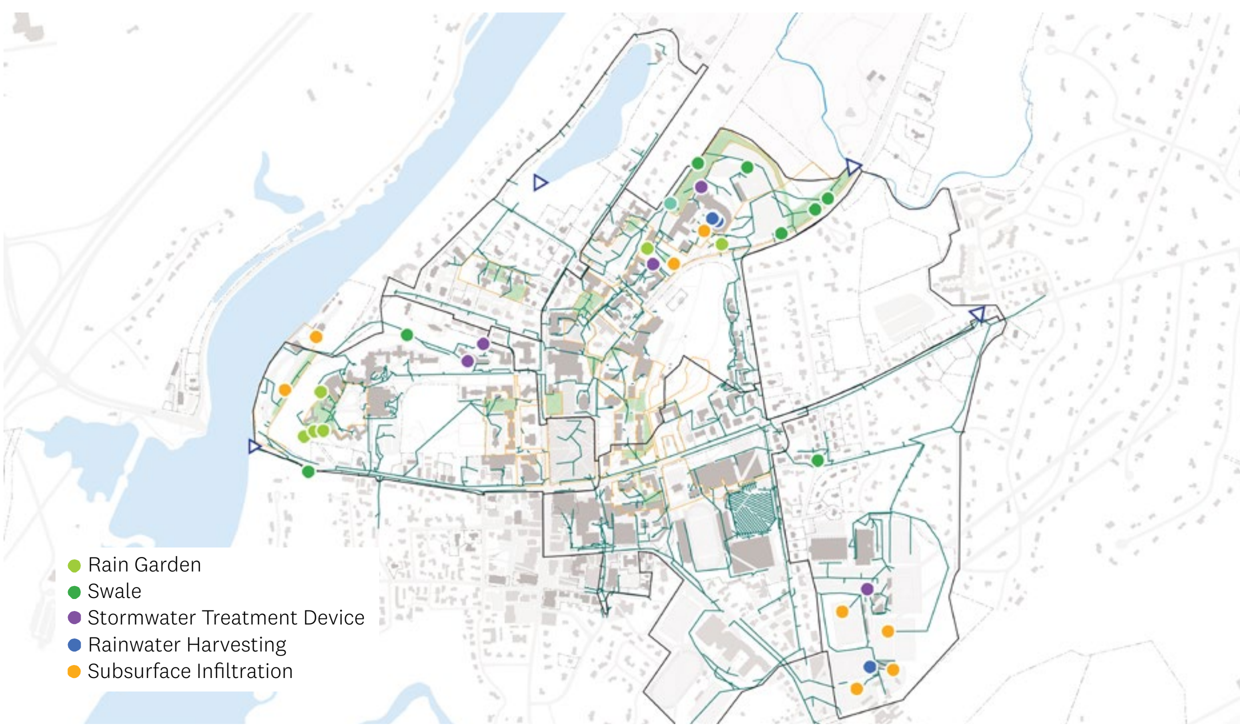
Existing Campus Sub-Watersheds

Existing Stormwater Conditions

The existing campus relies heavily on the use of catch basins and storm drain pipes to collect and convey stormwater to Girl Brook, Mink Brook and the Connecticut River. Much of the existing storm drain infrastructure is aging and does not have enough capacity to convey even today's 10-year rainfall event (based on the results of campus stormwater model developed by Dufresne Group, 2012; and the North Campus stormwater model developed by Ramboll, 2017).

The majority of stormwater runoff from the campus currently receives little to no treatment or mitigation prior to discharge to the storm drain system. Some stormwater management systems have been constructed in recent decades for large projects to comply with regulatory requirements, but these systems are working in isolation from one another and do not serve to manage stormwater beyond the individual project impacts.



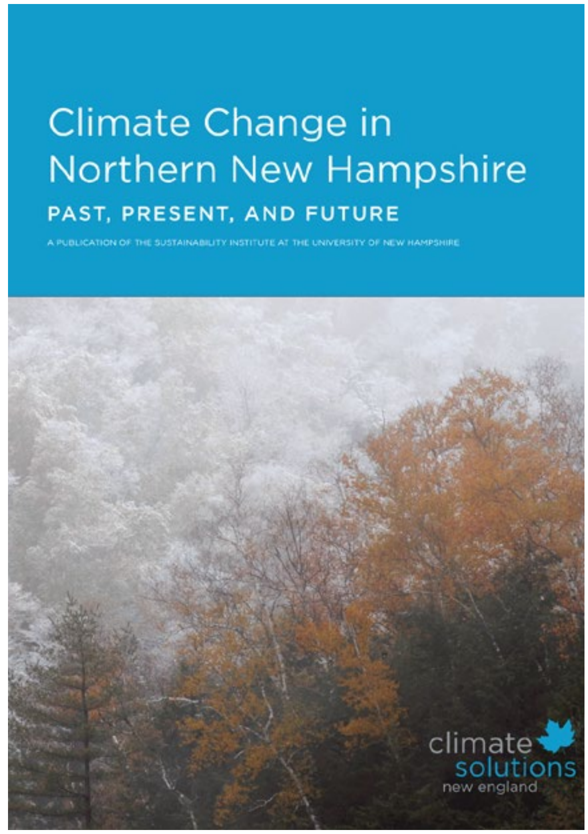


Existing Stormwater Best Management Practices (BMPs)

Climate Change and Resilience Considerations

Dartmouth College's campus currently experiences a variety of urban stormwater issues including surface ponding, aging and overtaxed storm drain pipes, downstream flooding and water quality issues. Without action, these current issues are expected to be exacerbated by the changing climate. More intense and frequent rainfall events will continue to cause nuisance ponding and erosion due to the rapid generation of runoff from pavement and compacted lawns that exceeds the capacity of catch basin inlets.

The predicted increase in the depth and intensity of storm events will continue to exceed the capacity of the existing storm drain system, presumably leading to surcharge pipes and more significant flooding in low-lying areas of the campus. And finally, the impacts of larger and more intense storm events will continue to cause erosion, downstream flooding, and water quality impacts in the receiving bodies (Mink Brook, Girl Brook, and the Connecticut River).



Existing Campus Land Cover Conditions

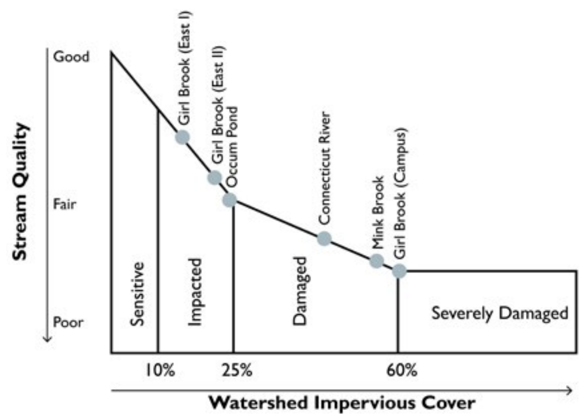
Goals & Targets

Water Balance Restoration

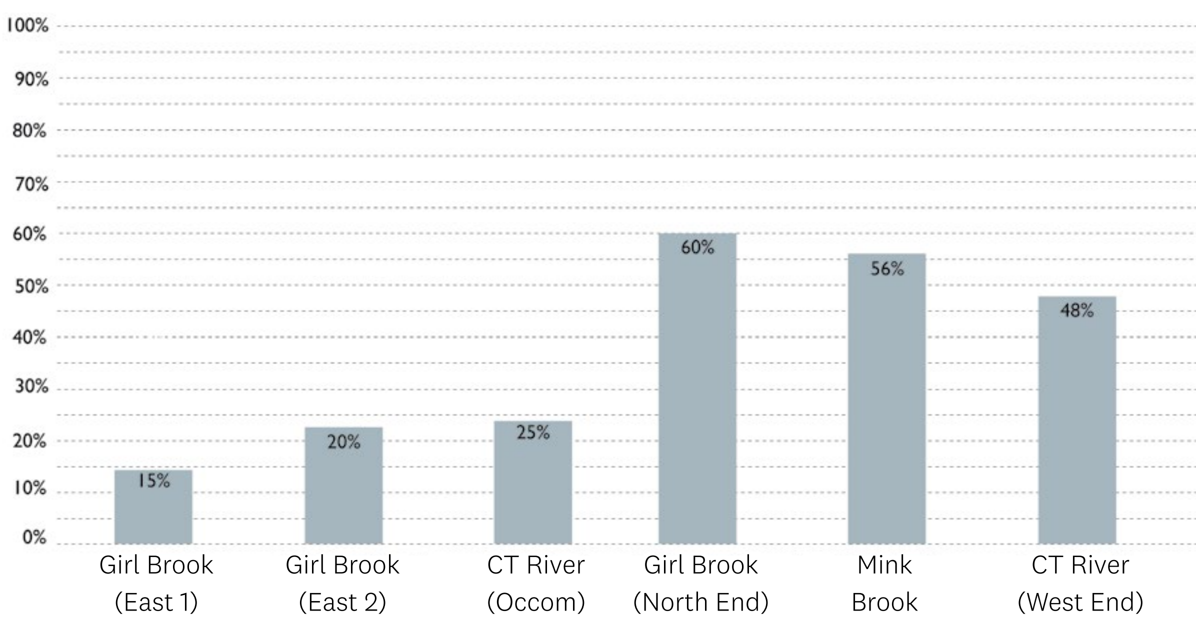
Although the campus looks and feels "green", the historic development on campus has gradually increased the amount of impervious area on the campus over time. The West End, Athletics District, and North End areas are highly impervious ranging from 48% to 60% impervious, respectively. The remaining, less developed, portions of campus have impervious cover ranging between 15% and 25%.

The Impervious Cover Model (ICM) was developed by the Center for Watershed Protection to relate surface water quality (state of impairment) to the amount of impervious cover in the watershed. Campus sub-watershed land cover conditions ranging from 15% to 60% correlate to "impacted" and "damaged" stream quality and watershed health conditions according to the ICM. The simple comparison of impervious land cover does not account for the benefit of stormwater management practices on the campus (see more detail regarding Effective Impervious Cover below).

Impervious Cover Model (Developed by the Center for Watershed Protection)



Summary of Impervious Cover (%) by Subwatershed



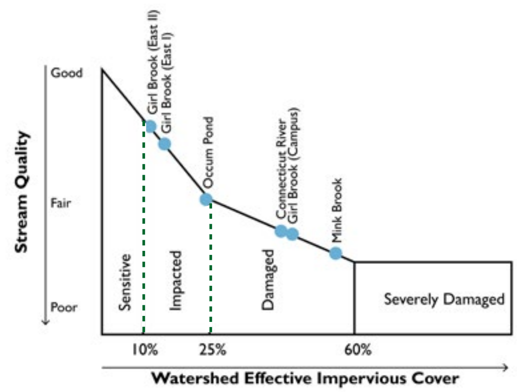
Effective Impervious Coverage Reduction

Although the removal of impervious surfaces and restoration of natural landscape would be an idealized approach to restore the health of the watershed and streams, the approach is not practical for the Hanover Campus at a large scale. However, Effective Impervious Cover can be reduced on the Hanover Campus using green infrastructure techniques which could be used to mimic the same benefit.

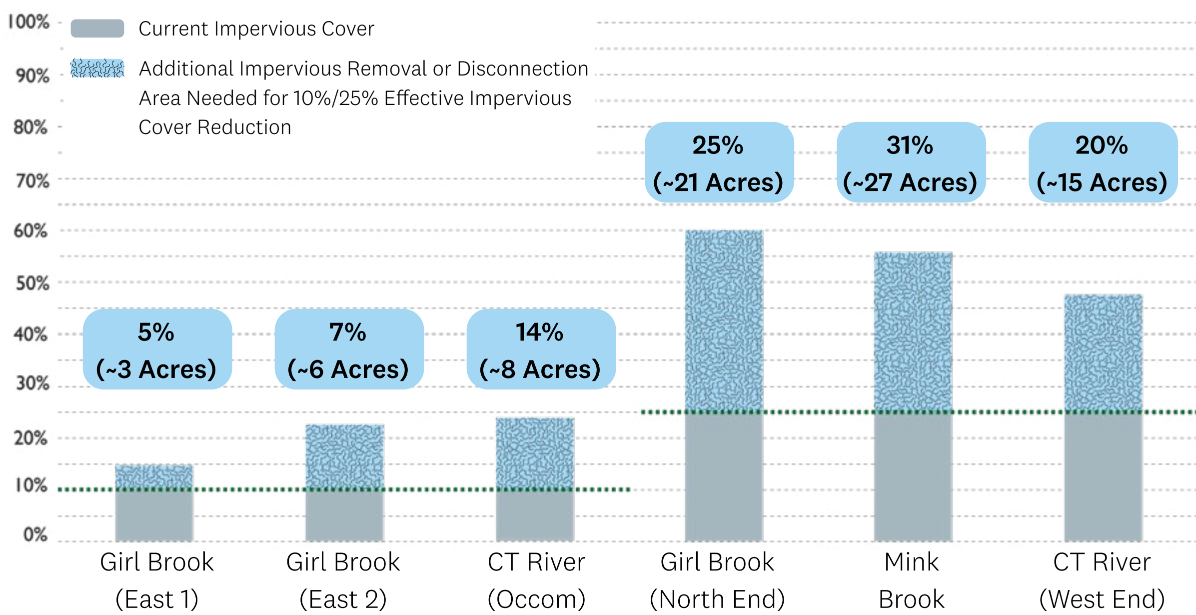
All impervious surfaces that drain directly to the storm drain system are defined as “Effective Impervious Cover” (EIC). The intent of the Impervious Cover Model is to account for all Effective Impervious Cover in the Watershed. Impervious areas that are “disconnected” from the storm drain system and instead are directed to green infrastructure/stormwater management practices that absorb, treat, and retain stormwater would not be considered part of the EIC calculation.

The Impervious Cover Model targets can be used as long-term goals for reducing the Effective Impervious Cover (EIC) on the Hanover main Campus to within the 10% to 25% range. The goals to reduce the EIC can be accomplished as part of the long-term development plan and integrated as part of project development, landscape, and infrastructure projects over time. Existing Stormwater BMPs that effectively absorb and retain at least the first 1-inch of rainfall from contributing impervious surfaces could be accounted for as a baseline removal from the Effective Impervious Cover calculations.

EIC Reduction Targets by Sub-Watershed



Effective Impervious Coverage Reduction Targets (By Subwatershed)

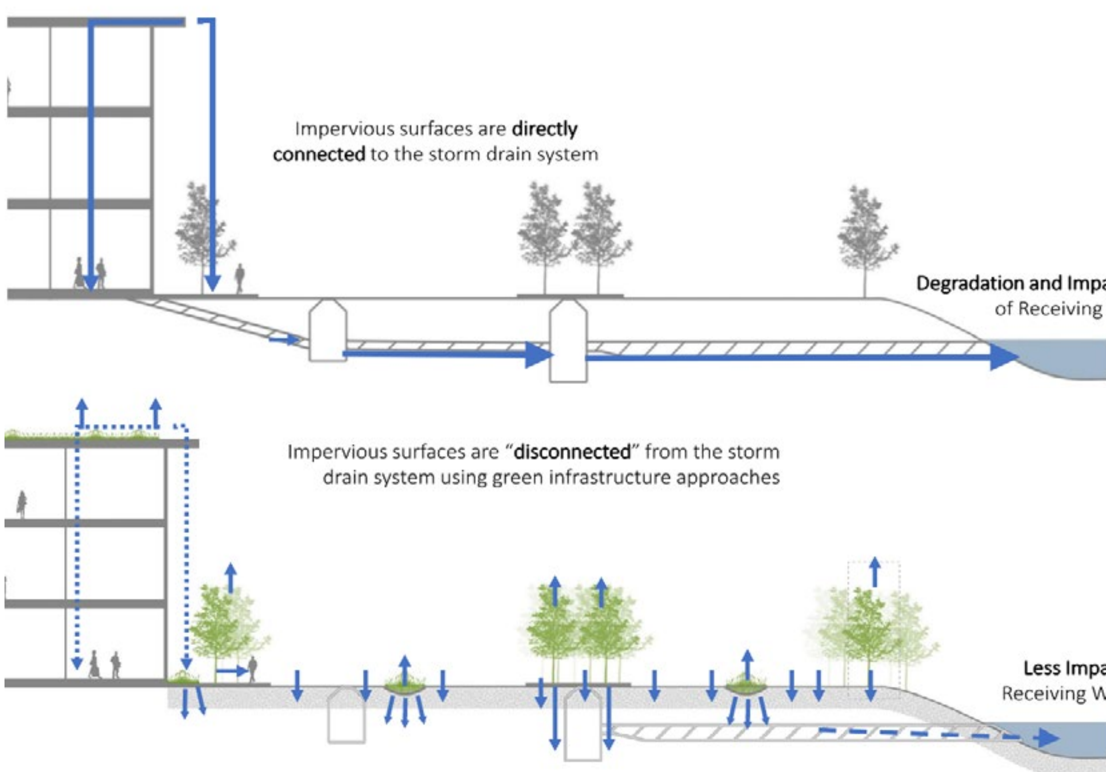


Rainfall Retention Standards

All capital projects, landscape projects, and infrastructure upgrades present an opportunity to incorporate green infrastructure practices and contribute to the overall EIC reduction described above. Although many large projects trigger regulatory stormwater requirements, small projects may not. While the regulatory stormwater requirements address water quality and water volume mitigation, state and local stormwater regulations do not require the use of green infrastructure, nor do they go far enough in considering future precipitation patterns and considerations. Stormwater regulations often focus on interval rainfall events (2-year, 10-year etc.) over a 24-hour period, but smaller storm volumes and more intense rainfall volumes are being seen and should be accounted for in future stormwater goals and targets.

Dartmouth College should consider adopting specific stormwater goals and targets for all campus projects. The goals should require all projects to meet specific stormwater performance requirements to absorb stormwater, emphasizing green infrastructure approaches to the greatest extent practicable. The stormwater goals should expand on regulatory requirements and could be based on the LEED and SITES rainwater management credits that require the retainage of the 90th to 95th percentile rainfall depth. All impervious areas that align with the rainfall retention standard could be accounted for in the EIC reduction goals that will be tracked at the sub-watershed level.

Traditional vs. Green Infrastructure Approach to Reduce Effective Impervious Coverage (EIC)



Planning Strategies & Approaches

As the Hanover Campus redevelops over time, a multi-pronged strategy to manage stormwater should be considered to protect and restore the health of the campus and watersheds. These approaches should also be optimized to ensure the campus is resilient to the anticipated impacts of the changing climate.

Natural Resource Protection and Enhancement
As Dartmouth College redevelops the campus, it is important to preserve the buffers to the stream channels, especially the more upland buffers that may not be regulated. The campus discharges to three major receiving bodies, the Girl Brook, Mink Brook and Connecticut River. The Girl Brook is highly constrained at the northeastern corner of the Dewey Lot. In the long term, this area should be explored as an opportunity to create new floodplain that helps cool and dissipate flows from the campus into Girl Brook. As Girl Brook meanders through the golf course, it will be important to maintain the existing vegetative buffers and consider stream enhancement and restoration projects. Any redevelopment on the golf course should have net positive impact on the stream.

Project-Based Implementation (Development and Redevelopment)
As development and re-development projects are considered, each project presents a significant opportunity to reduce the Effective Impervious Coverage (EIC) using green infrastructure techniques. **Every major project on campus should be designed to meet the Rainfall Retention Standards (e.g. Retain at least the 90th percentile rainfall depth on site).** All impervious surfaces within the project limit of disturbance should be "managed" in alignment with the Rainfall Retention Standards and contribute to the Effective Impervious Cover Reduction goals which can be tracked by sub-watershed.

As projects are implemented, the campus will gradually increase its ability to absorb more stormwater using dispersed green infrastructure (landscape-based and engineered) approaches such as green roofs, bioretention, planting that promotes infiltration, and other small-scale infiltration techniques such as permeable paving with free-draining crushed stone bases. This approach will serve as the first line of defense for absorbing rainfall and slowly releasing stormwater to the storm drain system. The campus "sponge" will help alleviate surface drainage issues and help alleviate pipe capacity issues by reducing the volume and rate of stormwater discharged to the system. This approach also is a first step to restoring the campus to a more natural hydrologic pattern.


Wet Meadow at Frick Park Environmental Center


Bioretention at Cornell University Plantations

Landscape and Open Space Integration

Landscape Projects provide opportunities to reduce impervious cover and create more absorptive landscapes. Landscape and open space projects should also be designed to meet the Rainfall Retention Standards for all impervious surfaces within the project limit of disturbance (walkways, plazas, etc.). Landscape Projects should be optimized to find additional opportunities to “disconnect” and manage adjacent impervious areas outside the project limit of disturbance (such as nearby roof leaders) to further contribute to the Effective Impervious Cover Reduction targets.

Landscape enhancement projects should be considered as opportunities to improve the long-term stormwater conditions, particularly projects that bring pockets of natural landscape into the campus. The landscape projects can provide locations for integrated green infrastructure, flood storage, buffer zone enhancement, and ecological stormwater management opportunities, and turf conversion to meadow.

Infrastructure Project Opportunities

As the campus converts to hot water distribution, the large diameter steam pipes will gradually be abandoned in place. Dartmouth College should explore the potential to repurpose the steam pipes for storing stormwater. This would require researching the structural and environmental viability of this approach. If the steam pipes cannot be used for stormwater storage, the trench associated with the abandoned steam pipes could be explored as a potential green infrastructure corridor using more surface-based approaches such as bioretention and infiltration trenches.

Knowing the existing capacity issues in the system, a campus-wide flood study to evaluate the long-term vulnerabilities in the system should also be considered. The flood study could be used to identify and prioritize locations where stormwater storage should be considered to protect Dartmouth College’s assets and critical services during the flood events. The study should also identify flood storage opportunities such as designing floodable landscapes, tanks, or other techniques in the flood-prone areas of concern.

Floodplain Restoration at University of Virginia

Bioswale at Salem State University

Policy Recommendations

Stormwater Standards for All Projects

Over time, Dartmouth College is anticipated to continue to implement redevelopment projects on campus, guided by the Strategic Master Plan. The key recommendation of this Plan is for Dartmouth College to adopt **Rainfall Retention Standards** that would apply to all campus redevelopment projects. The Rainfall Retention Standard would require all impervious areas within the project limit of disturbance to be retained on site and either infiltrated, evaporated, and/or reused. The Rainfall Retention Standard would be in line with the recommendations already in place for Rainwater Management under the USGBC's LEED and SITES Rating Systems. The recommended target for Dartmouth College would be retainage of the 90th percentile rainfall depth (approximately 1.1 inches) for all projects, using green infrastructure techniques to the greatest extent possible.

Tracking Progress

As described previously, the historic development of the main campus has resulted in urbanized stream and sub-watershed conditions, particularly in the North End and West End areas. Most of the impervious surfaces on campus are not treated or mitigated prior to discharge to the storm drain system, which has led to system capacity issues and impairment of the receiving water bodies. This Plan recommends that the College establish near- and long-term targets for reducing the **Effective Impervious Cover on the campus to 25% for the highly developed sub-watersheds and 10% for the less developed sub-watersheds.** The reductions can be achieved by "disconnecting" impervious surfaces from the storm drain system and instead directing them to green infrastructure stormwater management techniques that absorb, treat, and retain stormwater prior to discharge to the system. The impervious area attributed to all stormwater management systems sized in accordance with the Rainfall Retention Standard could be tracked as part of the EIC reductions.

Next Steps

The following provides a summary of recommended next steps:

1. Calculate the **"baseline" Effective Impervious Coverage** for the Campus Sub-watersheds by quantifying the performance of existing BMPs.

2. Confirm the **Rainfall Retention Standard** for all projects and incorporate into the Sustainability Guidelines and/or Project Performance Standards for all projects.

3. Consider updating the **campus-wide hydraulic model** and evaluating under various future climate change scenarios to identify near- and long-term vulnerabilities and flood risk in the system.