# "Ecologic-*L.I.* Sound"

## University of Connecticut

Registration number: M9


Team Members:
Kelsey Adamson- Environmental Engineering
Fiona Casey- Environmental Engineering
Ryan Gussen- Landscape Architecture
Alex Joslin- Environmental Science
Benjamin Zaccara- Landscape Architecture

Faculty and Staff Advisors:
Dr. Sohyun Park ASLA, SITES AP- Lead Advisor, Landscape Architecture
Dr. Juliana Barrett- Connecticut Sea Grant, CT NEMO
Dr. Michael Dietz- Natural Resources and the Environment, UCONN CLEAR
Dr. Mariana Fragomeni- Landscape Architecture
Sean Vasington PLA, ASLA- Director, UCONN Site Planning and Landscape Architecture
Ben Roccapriore- Facilities Director, Avery Point

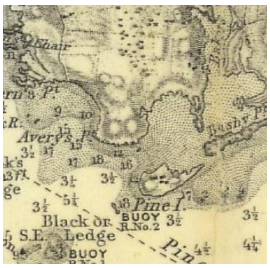

## *Abstract*


UConn Avery Point is a 73-acre campus located in Groton along the Connecticut coast. Surrounded by water on 3 sides, this peninsula is part of the tidal estuary known as the Long Island Sound. Development along the coastline has resulted in extensive habitat loss, with the few untouched areas that remain subject to adverse ecological effects. One of the major environmental threats arising from development stems from the increase in impervious cover and the stormwater runoff it produces. It is through the incorporation of green stormwater infrastructure on campus that we aim to lessen the impact of the built environment on the delicate Long Island Sound ecosystems. We designed these practices to support the marine science mission of Avery Point by providing collaborative, educational spaces and resources that increase awareness on the issues of stormwater management, maritime ecology, and coastal resilience. The system of practices within our design serves as a reference for various local biomes and their roles in pre-development hydrology. Starting at the water's edge and moving inland, these practices utilize plant species typical of the distinct coastal ecological communities found in the immediate area. Through the use of rain gardens, bioretention, constructed wetlands, and green roofs our design seeks to treat runoff through capture, remediation, and infiltration.

## Context

### *Campus*

One of UConn's five regional campuses, Avery Point is located on Connecticut's southeastern coast at the confluence of the Thames River with the Long Island Sound. In 1903, Morton Plant, a railroad, steamship, and hotel magnate built what is now known as Branford House, a Tudor-style 31-room mansion located on campus grounds. The estate was turned over to the State of Connecticut in 1939, and during World War II, was leased to the U.S. Coast Guard. In 1968, the estate became the Southeastern Campus of the University of Connecticut, which was renamed to the University of Connecticut at Avery Point. Avery Point acts as the University of Connecticut's Sea Grant Institution, working towards creating and maintaining healthy coastal environments and economies.



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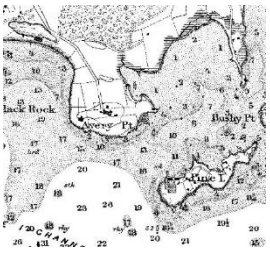

1917


1934


1951


2021

Avery Point is about 50 miles from Hartford, Connecticut's capital, about 130 miles from New York City, New York, and about 110 miles from Boston, Massachusetts. The campus includes a mix of building types, from the historic Branford house (1904), to the cutting-edge marine science building (2013). There are also a number of deteriorated and obsolete buildings on campus. Four large parking lots on campus to serve the campus, with additional parking around some buildings.

The campus is frequented by both students and the public. The Historic Branford House serves to host weddings and events, as well as public lectures. On weekends, the campus is one of the few places in Groton where the public has free access to the coast; it's beautiful coastal views attract dog walkers, kayakers, fishermen, and families enjoying a day on the water.

The 15-mile Thames River, adjacent to campus, is listed as priority impaired by the Connecticut Nonpoint Education for Municipal Officials (NEMO) MS-4 program, as well as category 5, 4a, and TMDL impaired by the EPA. The waters of the Long Island Sound around the site are also listed by the EPA as being in the 95% plus percentile for impaired waterbodies. Heavy industry and urbanization in the Long Island Sound area have created conditions that contribute to ecological deterioration and poor water quality. The Avery Point campus provides a glimpse into the land use practices typical of coastal Connecticut and how they impact the surrounding ecosystems. As seen on campus, the large areas of impervious cover and the collection of stormwater runoff into sewer systems discharging to waterbodies combined with a lack of native vegetation hasten the deterioration of the already compromised coastal environment.

*Development of the "Urban Sea"*

Spanning 110 miles from Hell Gate in New York City to Block Island, RI, the 1,268 square mile tidal estuary known locally as "The Sound" is a waterbody of incredible cultural and environmental value (fig.1). One of the country's most historically significant areas, the Long Island Sound region currently houses a population of around 9 million. From the establishment of Connecticut's early colonies in the late 1600's until the establishment of the Clean Water Act in 1972, much of the development that has occurred in the area was carried out with little regard for environmental consequence. Over 300 years of deforestation, urbanization, and industrialization along the coast have resulted in increased pollution and extensive habitat destruction. Often described as an "Urban Sea", the heavily developed Sound is also home to over 1,200 species of invertebrates, 170 species of fish, and dozens of migratory birds as well as a hugely diverse range of terrestrial and aquatic plant life. Large scale die-offs of plant and animal communities since the 1800's have marked the steady decline in the health of the waters. The value of the Sound as a healthy ecological system has been overshadowed by the economic benefits of increased industry. We are now beginning to see the economic effects of a disregarded natural asset such as the LI Sound; our economy and community health is directly linked to the health of the overall environment. Climate change and sea level rise, along with pollution, have created many problem areas in the region, many of which have already or may soon become unfit for use. Costly preservation and relocation efforts now underway could have been delayed or avoided had adequate land use practices and green infrastructure been incorporated into the development of the region's built environment. The Avery Point campus is in a unique position to promote and encourage change in land use practices, both as an educational institute and landmark in the local community. Although the campus faces some issues regarding sustainable stormwater management, we see an opportunity to create a green infrastructure system to foster environmental and community resilience.

Fig. 1- Connecticut and the LI Sound

## *MS4: General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer System Program*

The town of Groton is a municipality participating participates in the MS4 program. This EPA mandated program stems from the Stormwater Phase II rules of 1999 and requires involved towns to create stormwater management plans that lessen their reliance on city sewer systems. The goal of this shift is to intercept and treat stormwater runoff before it can enter city sewer systems, which often lead directly to water bodies. Stormwater builds in volume and velocity as it travels across impervious cover (fig. 2), collecting surface pollutants and increasing potential for erosion and flooding. City sewer systems are often overwhelmed by this runoff, and downstream water bodies are impaired by the pollutants it contains. There is a direct correlation between the amount of impervious cover and the health of adjacent and downstream ecosystems (fig. 3); as the percentage of impervious cover increases the area's ecological capacity decreases. Green stormwater infrastructure (GSI) practices, the foundation of the MS4 program, are used to disconnect areas of impervious cover from sewer systems and combat the adverse effects of stormwater runoff. These practices include, rain gardens, bioretention cells, bioswales, pervious pavements and asphault, green roofs, and rainwater harvesting. Another key feature of the program is the requirement for public education and community outreach on the subject of sustainable stormwater management practices. Three of our team members have experience working closely with UConn CLEAR faculty to assist municipalities in meeting MS4 requirements and have incorporated methods developed in those projects into our design process. With many large areas of impervious cover directly connected to sewer systems and discharging into the LI Sound, the Avery Point campus is ideal for disconnection through the use of GSI. There is also potential for cooperation between the

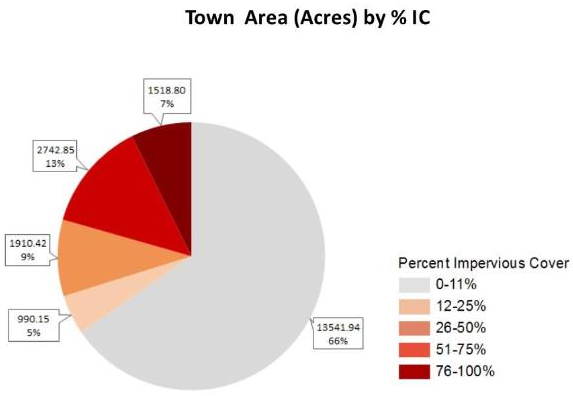



Fig. 2- Impervious Cover in Groton, CT

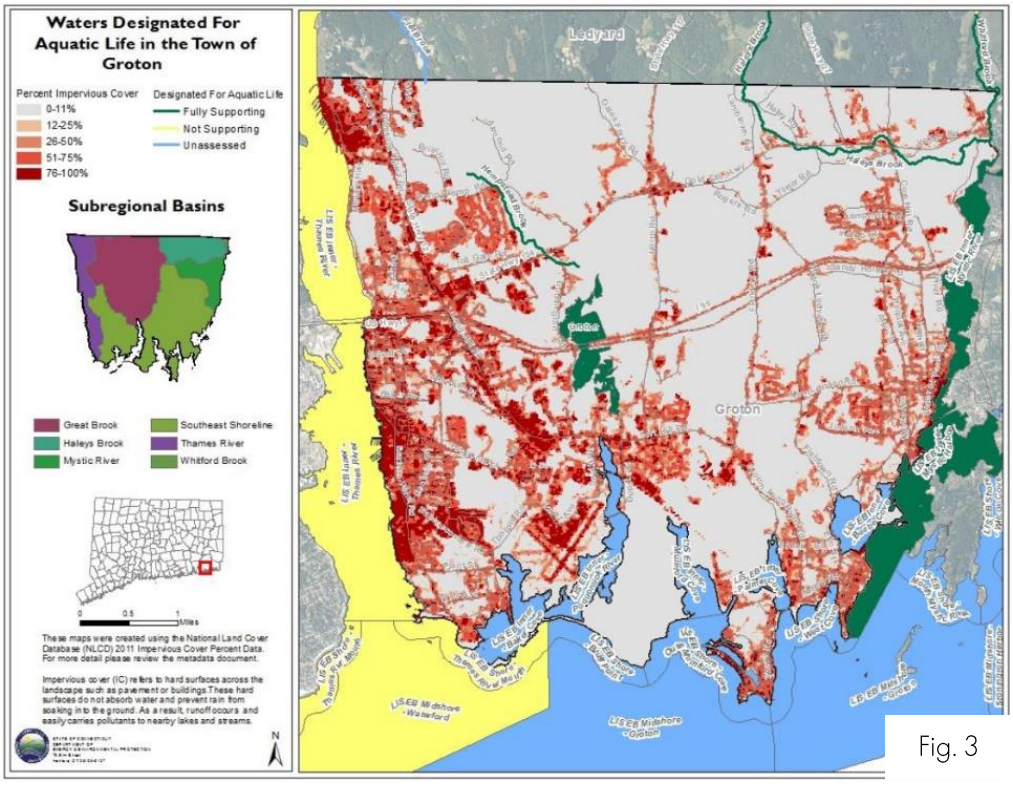



Fig. 3

University and the town in order to meet the MS4 target of 2% total disconnection of the town's impervious cover. Grants for installation of GSI may be available through the program on behalf agencies like the National Fish and Wildlife Fund, and town landscaping crews may be able to assist in installation and maintenance to offset costs of the GSI practices.

### *Avery Point Master Plan*

Our design was in part guided by the objectives laid out in the Avery Point Master Plan. The campus is in a unique position as both a center for academic research and a landmark for the broader community. The balance between the two site uses is vital to the functionality of campus, especially as enrollment continues to increase; dilapidated buildings and infrastructure are in need of demolition or renovation to accommodate and support the growing student body (fig. 4). In recent years, UConn has invested much into the coastal and marine science programs at Avery Point. The creation of new, marine focused, four-year degrees as well as the construction of the new Project Oceanology and marine sciences buildings, have established the campus as a center for marine research. Along with the improvement of facility conditions for undergraduate programs, UConn seeks to use further construction projects to promote greater integration of research into undergraduate programs, and to provide facilities for distance learning and collaborative learning and research. Implementation of a dormitory for students is also being discussed for the future. UConn has a university wide goal of net-zero energy use for the year 2050; we seek to incorporate sustainable energy production into our design. Our design is motivated by the goals set forth in the master plan, using stormwater management and sustainable practices as a foundation for academic, community, and environmental resilience.

**Space Needs Analysis Summary (with demolition)**

| | Existing | After Demo. | 2013 Needs | Future Add. |
|---|---|---|---|---|
| Academic Space (subtotal - ASF) | 43,365 | 11,577 | 52,519 | 40,942 |
| Classroom & Service | 13,047 | 1,299 | 10,784 | 9,485 |
| Teaching Laboratories & Service | 9,004 | 2,371 | 9,410 | 7,039 |
| Open Laboratories & Service | 1,228 | 0 | 1,875 | 1,875 |
| Research Space | 0 | 0 | 9,900 | 9,900 |
| Offices & Service | 17,832 | 7,687 | 16,050 | 8,363 |
| Other Departmental Space | 2,254 | 220 | 4,500 | 4,280 |
| Academic Support (subtotal - ASF) | 35,648 | 17,156 | 38,505 | 21,349 |
| Library | 10,803 | 0 | 12,231 | 12,231 |
| Assembly/Exhibit (subtotal) | 4,435 | 0 | 5,600 | 5,600 |
| Schlippe Gallery of Art | 3,274 | 3,274 | 3,274 | 0 |
| Branford Meeting Rooms | 3,774 | 3,774 | 3,774 | 0 |
| Physical Plant | 13,362 | 10,108 | 13,626 | 3,518 |
| Auxiliary Space (subtotal - ASF) | 29,477 | 24,794 | 34,289 | 9,495 |
| Physical Education/Research | 24,794 | 24,794 | 24,794 | 0 |
| Student Union | 4,683 | 0 | 9,495 | 9,495 |
| Campus-wide total (ASF) | 108,490 | 53,527 | 125,313 | 71,786 |
| Campus-wide total (GSF - 1.5x) | 162,735 | 80,291 | 187,970 | 107,679 |

Fig. 4

Key objectives from the Avery Point Master Plan:

- Improve facility conditions for undergrad programs
- Enhance collaboration between general education and research activities, and promote integration of research into undergraduate programs
- Preserve the historical context associated with Branford House
- Respect and protect the campus's unique and sensitive environmental setting, protect mature trees, and incorporate new landscaping representative of local vernacular
- Establish a stronger campus entrance identification off Shennecossett Road including directional signs to specific campus facilities, develop new walkways that establish convenient connections and reflect pedestrian desire lines, and replace/remove older parking lots and paved areas
- Physical separation of university/non-university activities is desirable

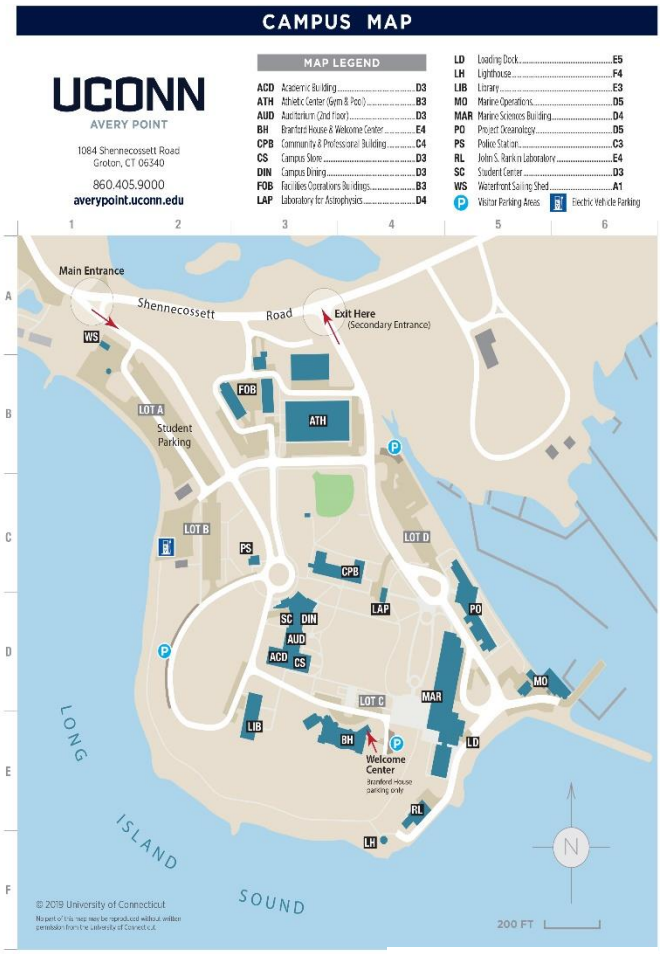


Fig. 5- Campus map

*Approach*

Adopting principles from urban ecology, we seek to establish balance between people and place through an environmentally sensitive design strategy. Utilizing methods developed by the UConn CLEAR Stormwater Corps, our team began the site analysis focusing on the disconnection of impervious cover from sewer systems. Following Connecticut's Small Municipal Separate Storm Sewer permitting guidelines, we aim to limit non-point source pollution by intercepting stormwater runoff before entering sewer systems. Green stormwater infrastructure practices are sized based on delineated drainage areas from the surrounding impervious cover and are used to conduct, collect, and clean stormwater runoff. Site use, student life and educational opportunity, and ecological impact are then considered to determine design specifics for each practice. Our goal is to provide a sense of place for UConn in the larger biotic community.

## *Site Analysis*

### *Terrestrial Ecology*

Fig. 6- LIS Coastal Lowland

Avery Point is located in the Long Island Sound Coastal Lowland ecoregion (fig 6), parts of this rolling coastal plain are highly urbanized, but the pre-development landform consisted of salt marshes, estuaries, dunes and beaches, and rocky bluffs. The waters of the LI Sound and tidal rivers provide a moderating effect on the region's climate; the Connecticut coast has one of the mildest climates in New England. Due to the mild temperatures, many southern plant species, typical of the SE Piedmont and Coastal Plain regions, reach their northern limit here. As temperatures increase with climate change, these species, such as sweet gum, post oak, and persimmon, become more desirable as landscape features while more northern species face increasing stress and health problems. The surrounding maritime forests are dominated by oaks, tulip tree, hickory, and black cherry, with the eastern dogwood dominating the understory, comingling with sassafras and serviceberry. These forests are dense and populated by vining plants like poison ivy and catbrier. Maritime shrublands are populated by bayberry, beach plum, switchgrass, and red cedar. American beach grass and prickly pear occupy the dunes along the shore, with *Spartina alterniflorus* (smooth cordgrass) salt marshes dotting the coastline. The Avery Point campus itself is almost entirely developed, with little to no pre-development plant communities present. Prior to development, the site would have shown examples of maritime forest, coastal shrubland, dune grassland, and extensive salt marshes. In attempts to recreate pre-development hydrology, we seek to utilize plant species indicative of the various communities previously mentioned in our GSI practices. These important species have developed over millennia to function as part of this coastal ecosystem, consuming stormwater, removing nutrients, and promoting infiltration. There is also great educational importance in showcasing these native plant communities and the wildlife to which they provide food and shelter.

### *Marine ecology*

The Long Island Sound is a 1,268 $mi^2$ tidal estuary situated between mainland Connecticut and New York's Long Island. This estuary is a place where freshwater and saltwater meet, this mixing of waters causes high nutrient levels that are supportive of a wide diversity of plant and animal life (fig. 7). Avery Point is situated near the eastern edge of the sound allowing for even greater biodiversity, sea turtles, cetaceans, and other open-ocean marine life frequent the area surrounding the peninsula. Large expanses of *Spartina alterniflora* dominated salt marshes and submerged eelgrass beds once filled the waters of the Sound, extensive development along the coast has resulted in the destruction and fragmentation of these important habitats. These two ecosystems supported a myriad of invertebrates such as horseshoe crabs and mollusks, brackish and saltwater fishes, seals and

cetaceans, and many native and migratory birds. The *Spartina* and eelgrass communities play an important role in supporting the Long Island Sound ecosystem by providing food and shelter as well as keeping the waters clean. However, pollution associated with stormwater discharge has contributed to habitat loss, associated with increased development also deprives the sound of its natural filtration system. This compounds issues of pollution and sedimentation, leading to further environmental damage.

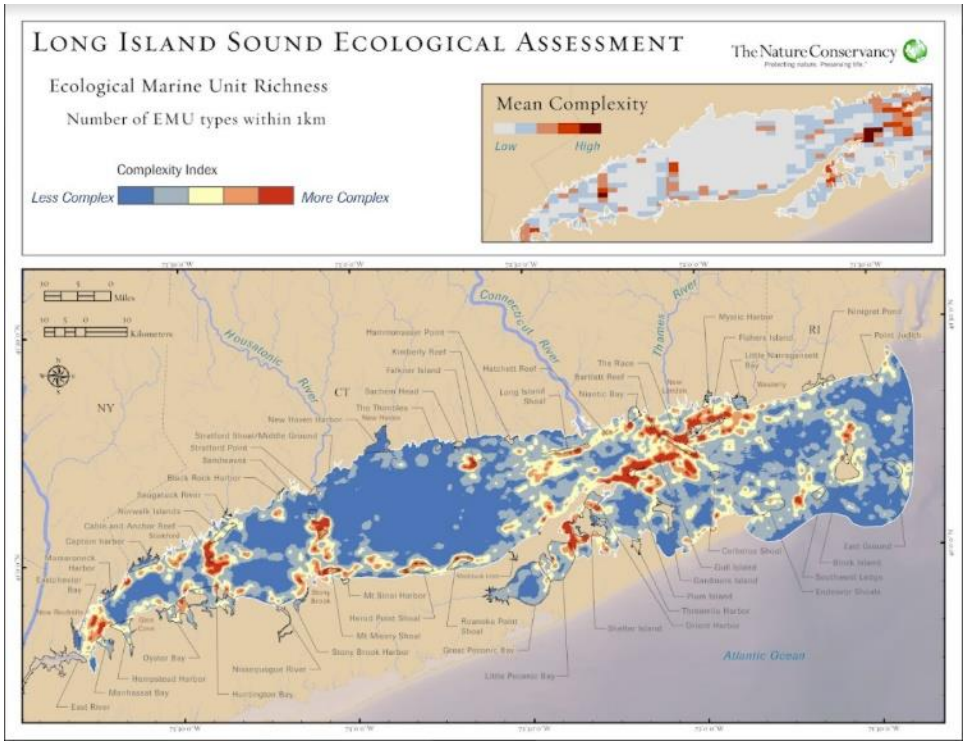



Fig. 7- Ecological Assesment

## *Hydrography*

Avery Point resides within the Southeast Coast Watershed, which deposits into the Long Island Sound. The Thames and Poquonnock Rivers both meet the waters of the sound on either side of the campus's peninsula. Out of the 26 waterbodies within the Southeast Coast Watershed, 64% have been assessed as impaired by the EPA. Runoff from rain and snowmelt can contribute significant amounts of pollution into the waterbodies within any given watershed. Land development, agriculture, lawn care, septic systems, and other industrious activities will affect a watershed's natural resources and water quality. As the last line of defense before runoff deposits into the Long Island Sound, Avery Point has a unique responsibility to further manage the watershed in which it resides. Watershed management at Avery Point is also important because it offers an opportunity for partnership and collaboration among all stakeholders

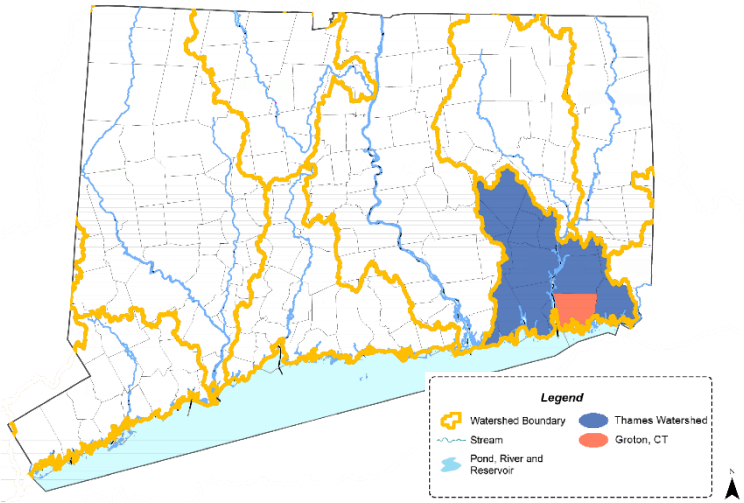



Fig. 8- Watershed

within the affected area. In line with our goal to bring UConn Avery Point closer to the larger ecological community, addressing watershed management, both upstream and down, is an essential component of our proposal.

*Climate and Weather*

Connecticut is located within the United State's Northeastern climate region, with the Avery Point campus situated at the southern edge of USDA plant hardiness zone 6b. This location creates a milder climate with few temperature extremes; the 30 year average maximum temperature is 79.5 °F in July, and 21.8°F in January. The Köppen Climate Classification defines the campus as Dfb, humid continental mild summer, wet all year, with no significant precipitation difference between seasons. Over these past 30 years, precipitation has ranged from a low of 34.71 inches in 2015, to a maximum of 64.65 inches in 2019.

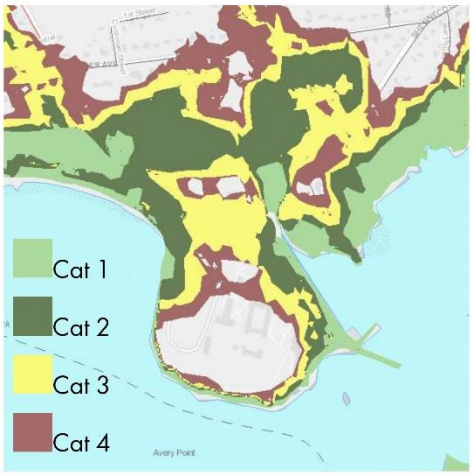


Fig. 9- Hurricane Innundation

While infrequent, hurricanes (fig. 9) and tropical storms can and do make landfall at Avery Point, which is located within Connecticut's Hurricane Evacuation Zone A. The perimeter of campus, including both entrances to campus, are within the CT Hurricane Surge Inundation Category 1 to 4 zones (2012), putting Avery Point at high risk for flooding, and the potential of being cut off from main roadway systems. In 2012, Superstorm Sandy (a tropical storm) reached campus, throwing rocks into parking lots, pushing 800-gallon holding containers ten feet, and moving the sailing shed 15 feet from its original position. Damages from this storm were estimated around $250,000. The Rankin Lab, a building next to the eastern coast of campus, experienced five feet of flood water, damaging laboratory equipment. The storm hit campus during high tide, overwhelming both inflow stormwater pipes, as well as outflow pipes into the ocean- causing a back pressure that was able to overcome the blockage unit in the pipe, allowing water to travel backwards into the storm system.

Road flooding projections through the Sea Level Rise Effects on Roads & Large Marshes Map Viewer produced by the Connecticut Environmental Conditions Online (CT ECO) in 2025 shows one of the two entrances to campus completely flooding and the second entrance being partially flooded between every 10 and 100 years, and by 2085, flooding increases at both entrances to between every 90 days and 10 years- as well as increased flooding on campus roads. In the worst scenario, the average monthly maximum for sea level rise is predicted to completely cut off the Avery Point Campus from mainland Connecticut- the campus would become an island.

*Soils/Geology*

Connecticut lies within the USGS physiographic region of New England Upland section 9b. The bedrock is Pennsylvanian sedimentary rocks, different from northern towns which fall under

Precambrian and Paleozoic granite, and towns directly across the Thames River, which are Silurian and Ordovician volcanic and granitic rocks.

While much of campus has a rating of moderate soil suitability for marsh migration, sections on the east and west portion of the campus have high suitability. From the Natural Resources Conservation Services Web Soil Survey The soil that is considered moderate for marsh migration is Narragansett-Hollis complex, type 74C on the WebSoil Survey, and makes up about 70% of the campus' soil. This soil is well drained, with a hydrologic soil group B, runoff class medium, and an ecological site of well drained till uplands. Its parent material is coarse-loamy eolian deposits over sandy and gravelly melt-out till, causing very rocky soil. The first few feet of the soil is silt loam, followed by gravelly silt loam, then very gravelly loamy coarse sand.

The next largest portion of soil, at about 30% of campus soils and listed as highly suitable for marsh migration, is Udorthents-Urban land complex, type 306. A typical profile of the soil is loam, gravelly loam (around 0.5 feet to 2 feet), and very gravelly sandy loam. This soil is well drained, has a runoff class of medium, and hydrologic soil group B.

## Circulation

Pedestrian and vehicular circulation is constricted to the central and northern areas of the Avery Point peninsula. Vehicular circulation is dominated by student commuters, due to the campus's location and lack of student housing. The campus consists of two northern entry points connected to Shennecossett Road. The main western entrance to campus is adorned with a small welcome sign and leads directly to the main student parking lot. Student movement focuses around the main quad and student parking areas. Its location to the Sound brings visitors during weekends who walk the seaside trail around campus as well as visit the Branford House, a historic banquet hall with a view of the estuary.

### *Runoff*

Current runoff from buildings, roadways, and recreational paths (fig. 10) is managed by stormwater basins around campus. Identified outlets consist of several pipes draining directly into the Long Island Sound, as well as a retention pond north of campus which also leads into the Sound. Impervious area is estimated to cover 33.3% of the parcel, with a significant amount of this

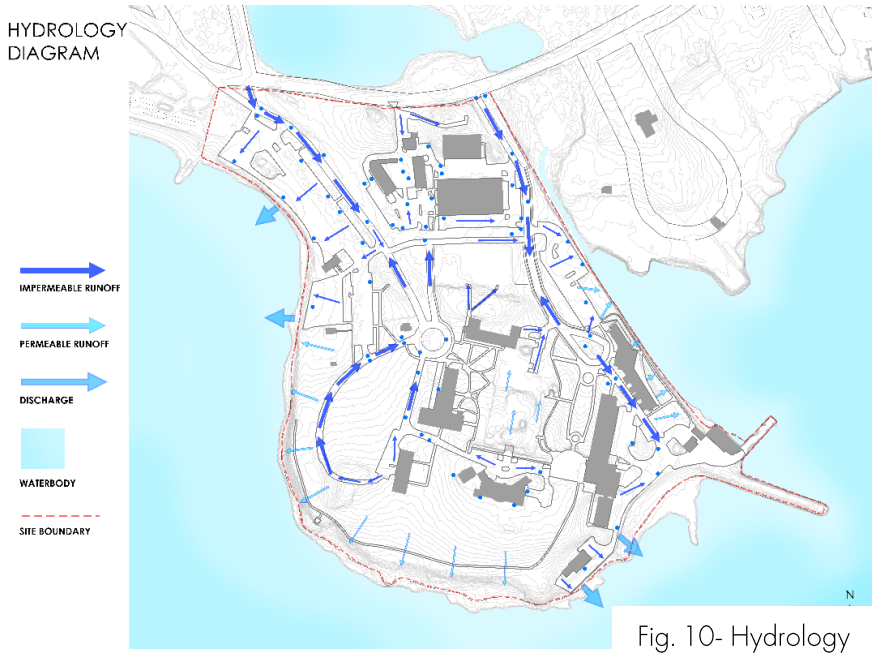


Fig. 10- Hydrology

runoff being directed into natural water bodies. Minimal low impact development is currently in place; however, small installations are located around the UConn Bookstore and Project Oceanology building. These practices consist of gravel infiltration areas and one small rain garden. Existing runoff values around campus were estimated using both the simple and SCS curve number method, using the assumption that most of the impervious cover resulted in untreated runoff.

## *Design*

### *Opportunities*

- Disconnection of stormwater runoff from sewer systems that discharge directly into the Long Island Sound, promote infiltration and removal of pollutants
- Creation of educational and research assets on campus, showcase GSI practices, living shoreline, native plant communities, renewable energy
- Creation of collaborative and event spaces, possible funding opportunity with public rental associated with Branford House
- Decrease the amount of impervious cover on campus through incorporation of pervious pavement and removal of unnecessary/obsolete paved areas. Establish better wayfinding system and pathway hierarchy
- Increase the amount of native vegetation on campus supportive of local wildlife
- Incorporation of renewable energy sources into design, possible funding opportunity for GSI practices
- Reduce erosion along seawall through bank stabilization and stormwater infiltration

### *Constraints*

- Numerous historical buildings on site require special permitting for any construction
- Potential for flooding impedes GSI functionality in certain areas, excess water and salt may harm plants, sand may clog GSI practices
- Shallow and exposed bedrock throughout campus limits construction potential, most areas suitable for development contain existing structures
- Extensive riprap along shoreline prevents development and plant migration
- Separation of university and public activities desired
- Views of LI Sound to be preserved to the south of Branford House and construction limited to the north

### *Master Plan*

The main goal of our design is to provide balance between people and place through the implementation of ecologically friendly GSI practices. We seek to create spaces that promote resilience for UConn as a part of the greater ecological community. To do so, we utilize native plant communities to emulate pre-development ecological conditions that are supportive of a healthy hydrologic functionality. Beginning with the plant material, our design reaches out to benefit university educational and quality of life goals, public site use and community engagement, and the local wildlife.

Our design begins at the most critical point for stormwater treatment, the ***shoreline***. As this marks the last opportunity for the treatment runoff, we wrapped the waterfront with vegetation. Simple phytoremediation plantings preserve the views and aesthetic of the campus, with the native plant community of beach plum, bayberry, and switchgrass helping to combat the invasive bittersweet, knotweed, and rugosa rose. At the northwest edge of campus, existing conditions are suitable for a dune planting of American beach grass and the lesser-known native cactus, the prickly pear.
At the southeast edge of campus, we designed a ***living shoreline***, utilizing oysters to protect the vulnerable *Spartina* marsh along the bulkhead. "Oyster-tecture" is used as a breakwater to lower the intensity of wave action, the oysters also provide food and shelter for marine life while filtering pollutants and keeping the water clean. Aside from being an excellent research opportunity for the university, there is the potential for revenue in the sustainable harvest of the shellfish. The structure provided by the oysters is used to support a boardwalk surrounding the salt marsh with sweeping views of the LI Sound and Pine Island.

The northeaster section of waterfront contains a deteriorating ***seawall*** being assaulted on two fronts by erosion from stormwater runoff and wave action from the sea. During the construction of the Project Oceanology building, a very light subbase was used that triggered shifting and excessive underground runoff; in order to mitigate this, ***bank stabilization plantings*** (fig. 11) are featured on the hillsides on both sides of the building. "***Oyster-tecture***" is also suggested for implementation in areas below low tide along the seawall; this will lessen the impact of wave action on the exposed seawall.
Moving to the interior of campus, the most notable factor contributing to excess stormwater runoff is the sheer volume of paved parking areas. Many of these parking areas are in deteriorating conditions; instead of replacement, we suggest the implementation of an ***eco-parking garage***. This garage utilizes vertical space to offset the need for paved surface area throughout campus. Equipped with a green roof and solar arrays, this environmentally friendly structure harvests rainwater and provides energy to campus with the potential to return energy to the grid to offset its cost. Two other buildings on campus, the Athletic Center and the Community and Professional Building, as well as a potential dorm for a future residential population, are suitable for ***solar green roofs***, and the surrounding parking to be preserved is suitable for pervious asphalt.

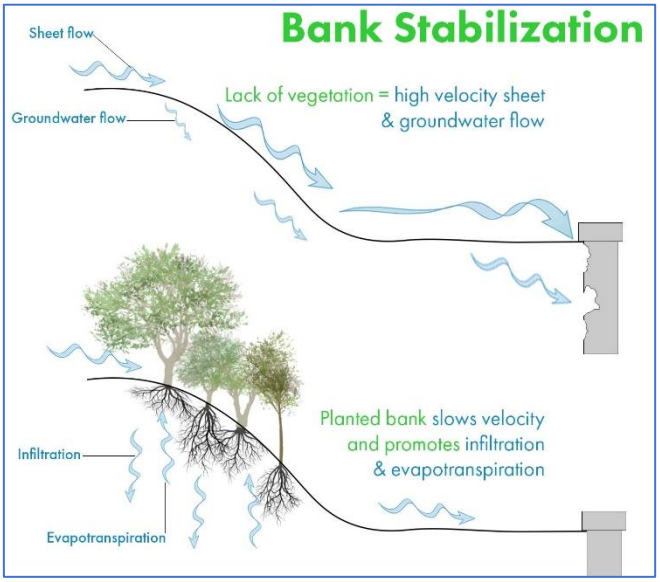


Fig. 11- Bank Stabilization

Due to the constantly changing site uses throughout campus's history, the system of roads and pathways lack an adequate hierarchy supportive of current site conditions. With the elimination of

some parking areas, connecting roads and pathways can also be removed, creating a better flowing path of circulation through the site. New pathways utilizing permeable pavers are to be implemented along more direct lines to key areas on campus. The existing pathway to the south of Branford House uses personalized pavers, with messages and names from donors adorning its length. This is a great funding opportunity for the new permeable paver walkways and encourages community investment in the promotion of sustainable practices. Bioswales and rain gardens along the preserved roadways provide a sense of direction and mark entrances and exits, while treating runoff from the impervious surface.

At the *campus core*, GSI practices are designed to fit the local landscape vernacular. Traditional, formal New England planting styles are used in *rain gardens* (fig. 12) to create a sense of place different from the more ecologically focused perimeter of campus. Following the goal of separation of public and university campus uses these stormwater practices will mark a transition in site use, letting visitors know they have entered a different space altogether. In the quad, we suggest an indoor/outdoor collaborative center showcasing ecologically focused LID practices. These include an *Amphitheater* equipped with native plantings and bioretention, and an events space/dormitory equipped with a solar green roof.

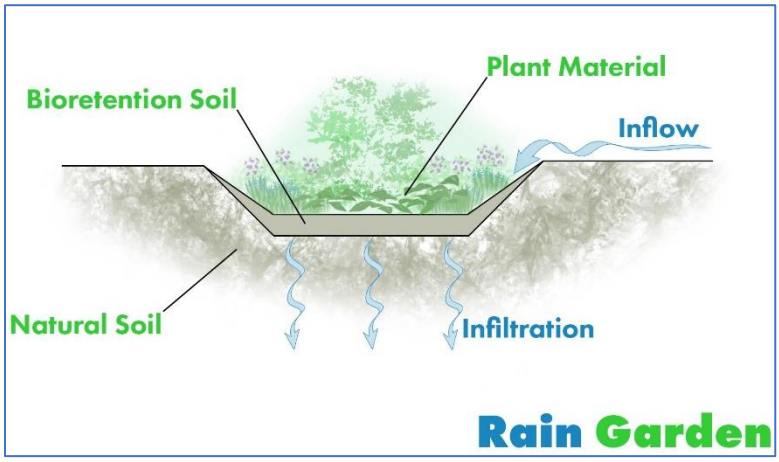


Fig. 12- Rain Garden

## Phasing

Phase, 1-5 years:

Less intensive green stormwater infrastructure measures are implemented to showcase their value to the UConn community and garner support for future projects. These include, rain gardens, bioswales, and bank stabilization plantings. "Showcase" pervious asphalt installation at Athletic Center. Work begins on establishing riparian buffer and *Spartina* salt marsh. These practices, once their value is proven as environmental and educational assets, will help garner support for subsequent steps in our phasing process.

Phase 2, 5-10 years:

Oyster reefs are implemented to protect established *Spartina* marsh and newly renovated seawall. Boardwalk constructed around the *Spartina* marsh. Pervious pavement is installed in additional key locations. Solar green roofs implemented at Athletic Center and Professional and Community Building in cooperation with Groton Utilities.

Phase 3, 10-25 years:
New dorm, equipped with green roof and solar array, is constructed to accommodate a residential student population. 150 space parking garage is constructed with green roof and solar array and obsolete surface parking is removed. Maritime forest arboretum is planted in southern half of removed parking areas.

## Cost

Our costs (fig. 13) were determined using broad range estimates developed by the UConn CLEAR Stormwater Corps. Our design would likely be on the lower end of the price-range, due to the lack of major soil amendments required, naturalistic plant palette, and avoidance of the use of underdrains. Construction of buildings was not calculated as these are possible university master plan projects.

| PRACTICE | AREA (sq ft) | AREA TREATED (sq ft) | COST MINIMUM | COST MAXIMUM |
|---|---|---|---|---|
| Green Roof | 63,250 | 63,250 | $442,750 | $2,227,000 |
| Removed Pavement | 12,107 | 24,860 | $113,000 | $339,000 |
| Constructed Wetlands | 10,806 | 20,003 | $54,030 | $324,180 |
| Phytoremediation | 37,000 | N/A | $74,000 | $259,000 |
| Permeable Pavement | 14,609 | 4,167 | $74,161 | $169,512 |
| Rain Gardens | 9,790 | 66,008 | $39,160 | $156,640 |
| Bioswales | 5,538 | 33,228 | $24,921 | $110,760 |
| Arboretum | 217,800 | N/A | $1,000 | $10,000 |
| TOTAL COST | | | | **$3,596,092** |

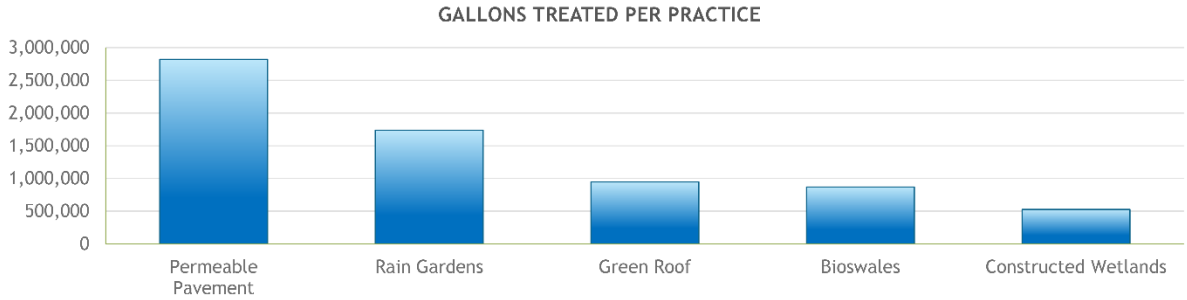
Fig. 13- Cost

## Funding

Because of our multi-faceted design approach, a wide array of grant and investment opportunities exist to fund implementation. UConn, as a non-profit organization, is eligible to apply for many federal grants and is in a unique position to educate students on green stormwater infrastructure and the process of grant applications. Viable options include, the Clean Water Act's Section 319 Non-point Source Grant (>$500k), the Department of Energy's State Energy Program (~$700k), and the CT Urban Forest Council's Urban Forestry Climate Change Grant (>$37k). Additional grants such as the National Fish and Wildlife Fund's Five Star and Urban Waters Restoration Program (~$50k with matched funds) have been awarded to multiple colleges and universities for green infrastructure projects.
Potential partnership with Groton Utilities is also a potential source of funding. The energy provider to Avery Point, Groton Utilities has expressed interest in the creation of a "micro-grid", utilizing the campus as a solar farm to provide energy to the surrounding community. The production of solar energy will help to offset the cost of the green roofs incorporated into the array's design.

## Design Performance

Our stormwater management practices were designed to treat runoff from a 1" rainfall event. These events account for around 90% of storms in the state, contributing to a total average rainfall of 48" per year. Performance totals (fig 14) are based on this average yearly rainfall, drainage area treated, and nutrient reduction coefficients developed by Dr. Daniel Fink. Through our design we were able to reduce the impervious surface area on campus by 29%, and further treat a significant portion of the remaining surfaces.




| PRACTICE | AREA (sq ft) | AREA TREATED (sq ft) | NITROGEN (lb/yr) | PHOSPHORUS (lb/yr) | GALLONS TREATED (gal/yr) |
|---|---|---|---|---|---|
| Permeable Pavement | 21,189 | 107,081 | 29.28 | 3.72 | 2,819,777 |
| Rain Gardens | 9,790 | 66,008 | 18.05 | 2.29 | 1,738,197 |
| Green Roof | 63,250 | | 17.29 | 2.19 | 946,347 |
| Bioswales | 5,538 | 33,228 | 9.03 | 1.15 | 869,730 |
| Constructed Wetlands | 10,806 | 20,003 | 5.47 | 0.69 | 526,715 |
| TOTAL GALLONS | | | | | **6,900,766** |

Fig. 14

## Maintenance

Green infrastructure and nature-based solutions are very important in mitigating the amount of water entering storm systems and being directly deposited into Long Island Sound. Funding and maintaining these practices is critical to the work that we propose.

Permeable pavements will require quarterly maintenance in the form of vacuuming. Because the site is coastal, extra attention will need to be given to removing sand in order to avoid any extra costs associated with clogging. Theoretically, the use of permeable paving solutions will allow for the use of less salt/sand. As snow melts on these surfaces, they allow water to infiltrate, as well as prevent frost heaving, which is an issue on many impervious counterparts. Maintaining permeable pavement will save more money in the long run than continuously replacing impervious surfaces.

Rain Gardens, bio-swales, and bioretention cells will require periodic weeding as well as removal of debris. Monitoring infiltration rates and soil testing will need to be done at least every 3-5 years in

order to prevent any issues such as flooding and damage to property. Functionality and aesthetics are equally important for maintaining these practices.

Green roofs require periodic weeding for 1-2 years. The replacement of any plants that die or inhibit the practice's functionality is also important. Regular inspections will be needed to ensure that the building and drainage system are sound.

All practices must be regularly monitored to ensure proper function for what they were designed to treat during storms. Any overlapping or significant storm events may cause issues with the proposed systems. Maintaining and monitoring is an essential component when factoring cost. Routine inspections and upkeep of these practices will lessen the risk of damage and unnecessary cost.

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