Building a Resilient Trail

Guidance on preparing for Climate Change on the Shoreline Greenway Trail.

SUMMER 2025

Contents

Introduction

Aims of this Report

As our climate begins to change around us, it is crucial that the teams managing our critical infrastructure have the vision and tools to adapt to new conditions and acute climatic hazards. This report aims to provide the Shoreline Greenway Trail team with the foundational information and actions to ensure the trail as it currently exists **remains resilient to the impacts of climate change**, whilst also empowering board members to design the future trail so that it improves the resiliency of both the trail itself and the wider community at its heart. This report includes some key recommendations, with links to further reading for technical specifics.

This report has been created as part of the Shoreline Greenway Trail internship program, which is generously funded by the Greater New Haven Green Fund.

What do we mean by resilience?

Throughout this report, the term 'resilience' is referring to the quality that allows communities and infrastructure to withstand, and bounce back from, the effects of climate change. This definition has its roots in a long academic study of resilience, and reflects the definitions used by large organisations - such as the IPCC who define resilience as: 'the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation.' This longer definition demonstrates how interconnected resilience must be - it's not just about ensuring a home or a business can withstand an event such as flooding - but also that its wider context, both natural and man-made, is resilient too.

By championing resiliency, a team or organisation is helping to ensure that the infrastructure they maintain and the communities they serve will be better protected in the face of our changing climate. It's a method of forward planning so that bridges, roads or homes built today will not need to face the choice of being rebuilt or facing significant damage in the future. Remarkably, the best resiliency plans often include elements that actually help reduce or sequester carbon emissions - allowing communities to not only adapt but also lessen the risk of the hazards they face at the same time. Designing with resilience at the forefront does involve a level of flexibility, and openness to change, but it also presents you with a wide number of opportunities to make your projects healthier, safer, and more likely to thrive.

What you need to implement to build resilience is different per project. Interventions can include: hard infrastructure such as larger culverts or reinforced pillars, green infrastructure such as tree planting or green walls, evacuation or management plans for extreme events, and education sessions. In this report, we'll reflect on what is needed for trails in a coastal landscape like Connecticut, focusing on specific stretches of the Shoreline Greenway Trail.

Trails as part of a resilient world

Traditionally, if you examine resiliency reports, they focus on infrastructure such as buildings, roads, pipelines, and powerlines. However, as we start to see the impacts of climate change in our towns and cities our purview for what needs to be made resilient is widening. In fact, we're understanding that everything must be considered as part of a much wider resilient system.

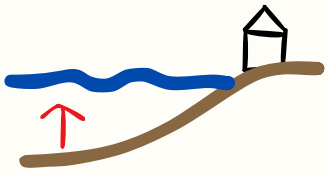
This acknowledgement can be seen in the growing literature on the relationship between trails and resilience - including two reports from the Federal Department of Transportation in 2023. **So, what role must trails play in our wider community's adaptation to climate change?**

Making Trails more Resilient

Firstly, trails themselves must be designed, upgraded and maintained so that they are prepared for both chronic and acute climate impacts.

Examples of **chronic impacts** include: increasingly hot weather, a shift in rain patterns to heavier rains with periods of low precipitation in between, and sea level rise. Adapting to chronic impacts means recognising that the baseline of what is normal has changed. It's understanding that events such as short term heat waves or one-off heavy rains that caused minimal damage historically need to be designed for as they become commonplace and begin to cause problems.

Examples of **acute impacts** include wildfires, hurricanes, flood events and storm surges. To adapt to an acute impact a trail manager has to heighten the definition of what a significant extreme weather event is, as previously 100-year events occur instead once a decade or once every couple of years. It's building a trail that is prepared for these extremes, and more importantly has procedures and features in place that allow it to recover as quickly as possible.



Designing trails this way will become increasingly important, as transport infrastructure - including trails - is predicted to be some of the worst hit by climate change. Building or updating trails to resiliency standards reduces the maintenance needed in the long term and allows trails to be used well and remain open as much as they can.

Trails as Resiliency Infrastructure

Secondly, trails themselves can make communities more resilient through several means.

To start, resiliency features can be built straight into the trail meaning that they are able to reduce the impact of climatic hazards for the wider community. For example, in a wild-fire prone forested area, trails can be designed as fire breaks, gaps that are designed to prevent fires spreading. For another example, trails can be designed with permeable paving and sustainable urban drainage (SuDs) systems alongside them, so they actively work to soak up water and reduce surface flooding in heavy rainfall events. Trails are particularly well placed for this sort of use - as they are often already green corridors and can allow for resilient solutions that are not yet permitted on traditional road ways (i.e. permeable paving).

Next, it's important to view trails as crucial infrastructure for wider community resilience. We saw this in the 2020 COVID pandemic, that trails played an important role in supporting the physical and mental health, as well as all round wellbeing, of people across the world. Utilising trails not only gives us the opportunity to improve our physical health - and be better prepared for some of the negative health impacts expected by our warming climate - but also provides opportunities to meet with your neighbours and volunteer to support your local area.

In fact, trails that link together communities and encourage non-car transport between them can see more people being actively involved in the shops, organisations and activities directly in their local area. Finally, trails give users the opportunity to frequently engage with nature in their local area, and in turn make the public more aware of the changing weather patterns and what might need to be done to both mitigate, and adapt to, them.

Resiliency on the Shoreline Greenway Trail

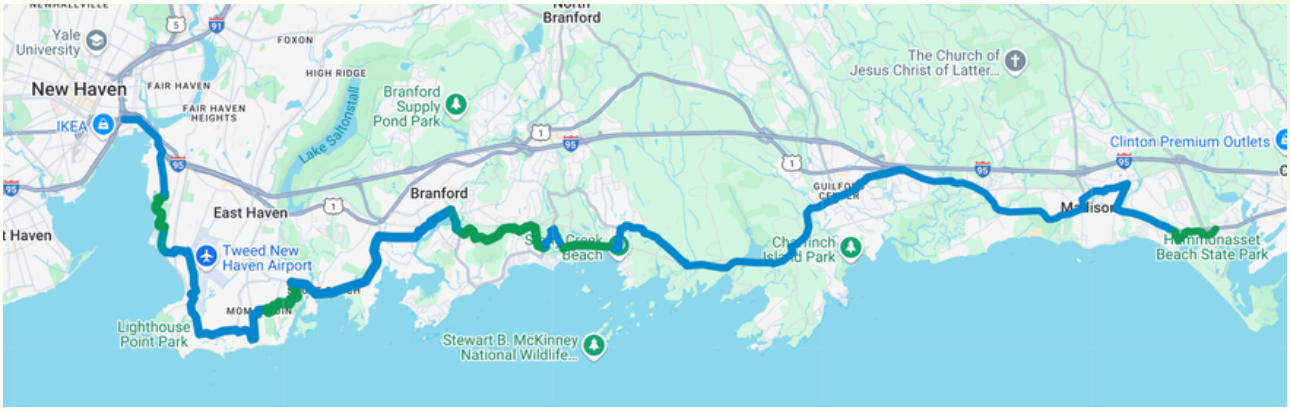
About the Trail

The Shoreline Greenway Trail is a 30-mile multi-purpose trail stretching from New Haven in the West to the Madison/Clinton town border in the east. The route includes a combination of on-road sections, with three key off-road sections in East Haven, Branford and Madison (marked in green on the map). There is an additional short off road section through East Shore Park in New Haven - but for the sake of this report is not included as a key off-road section. The off-road sections are not standardised and each has a different character.

The **East Haven** portion measures 1.6 miles in total. It is in two sections that consist of hard packed gravel through woodland. There is one portion with a significant gradient and some small bridges.

The **Branford section** has four different sections and measures in total 2.5 miles. From east to west, the Birch Road section is relatively flat with packed gravel, and the Tabor trail section is paved and flat. Next, the Young's park section is an unmade hiking trail - with many obstacles - and finally, the Trolley Trail section is flat gravel with a small bridge. The trolley trail section is a combination of wooded areas and open marshland. Lastly, the **Madison section** is 1.3 miles with a short boardwalk, and is in a wooded area with one or two open sections.

Throughout this report when we refer to the 'existing trail' we're primarily referring to the 5.4 miles of finished 'off-road' trail. There are other completed sections that are on roadways - for example in East Haven - that are considered but are not the focus of this report. When we refer to 'new sections' of trail, it is any section highlighted in blue below that has not yet had work in affiliation with the trail to improve access for walkers and cyclists. In addition, the report also gives recommendations in light of potential off-road routes that will differ from the current route provided.



The Climate Change Impacts facing the Trail

Heavy Rain

One of the clearest impacts of climate change to towns surrounding the Shoreline Greenway Trail is more intense rainfall. **The number of days with heavy precipitation in New England increased 71% between 1958 and 2011**. In general, this poses a significant risk to many in the state, as heavy rainfall can lead to flooding, erosion and salt-water intrusion. For the Shoreline Greenway Trail, the specific concerns are:

- **Erosion**: Already seen on both the existing Madison and East Haven trail sections, heavy rainfall can lead to the displacement of the gravel on soft surface trails, which can ultimately lead to a trail being difficult or impossible to pass.

- **Flooding**: Particularly on the paved sections of trail, lots of intense rainfall can lead to localised flooding. For example, the **bridge over the West River in Guilford on Route 146,** which is part of the proposed Shoreline Greenway Trail route, floods whenever there is intense rainfall. Even relatively small flood instances can lead to the trail being difficult to use, and the build up of water on either paved or unpaved surface will lead to damage.

Four Types of Erosion on Soft Surface Trails

- **Rain drop erosion -** soil particles are dislodged by raindrops and can then be transported by run off.

- **Sheet erosion** - surface storm water runoff travels across the trail, affecting an entire layer of exposed soil.

- **Rill and gully erosion** - the runoff concentrates into small groves cutting into the trail's surface.

- **Channel erosion** - occurs when gully erosion is allowed to continue uncontrolled and deep ruts or washouts are created.

On the Madison section of the trail we have seen examples of all the above, most notably channel erosion on one of the trail's bends. (See below)

Storms and Hurricanes

In Connecticut, climate change is likely to make tropical storms, hurricanes, and nor'easters more damaging to our local communities, and the Shoreline Greenway Trail.

The super storms of Irene and Sandy and the damage they did along the shoreline is still present in the memory of many residents, and climate change is likely to mean storms such as these hit our communities more regularly with impacts such as high winds, flooding and storm surges. Nor'easters, a type of storm that occurs in New England from late Fall to Spring with strong north-easterly winds and snow or rain, have become 20% more destructive since 1940.

What is the impact of these storms on the Shoreline Greenway Trail?

Firstly, **high winds** can lead to the downing of trees on our wooded trails. This not only means immediate attention is needed to make trails safe to pass if a tree blocks the right of way, but also can lead to a thinning of the tree canopy, which in turn reduces the shade provided for the trail.

Secondly, a combination of **heavy rain and storm surg**e can lead to sudden, and dramatic flooding across the trail. For example, in the events of super storm Sandy and Irene the storm surge came as far up as the East Haven road-route, and potential routes through Cosey Beach.

As well as damaging homes, this damaged the roadways and left debris that needs to be cleared to allow the trail to be passable. On the off-road trail section in Branford, **a clean up effort was needed** after Irene due to the litter and branches that were blocking the trail.

Even during a relatively mundane storm, there are areas of the trail that - especially as our climate warms - will flood even during a 10 year storm. For example, **Meadow Street in Branford** that currently serves as an on-road section of the train is likely to flood significantly in the future during relatively common storms.

Meadow Street flooded following Hurricane Irene.

Heat Waves

In Connecticut, climate change will mean significantly warmer temperatures - especially in the summer and fall. **On current emissions tracks it's predicted that by 2050 the number of heat wave events per year will double from 4 to 8.** Prolonged periods of extreme heat and hot weather can lead to the following issues for the trail:

- **Physical Damage** - Firstly, prolonged hot weather can lead to significant damage to asphalt trails that will eventually warp in high temperatures, meaning they need to be replaced. Secondly, hot weather and accompanying drought puts stress on nature alongside our trail. This can have wider impacts on ecosystem resilience, but specifically for the trail can lead to the loss of trees that are being used for shade. Thirdly, boardwalks made from plastic - as the one in Madison is - will age faster when exposed to high amounts of UV. Therefore, sunnier weather can lead to them needing to be replaced more frequently.

- **Usage Rates** - Generally warmer temperatures can lead to increased trail usage - which inevitably leads to more damage. However, extremely high temperatures can lower trail usage - for example one study in Texas found that pedestrian's trail usage peaked at 63F, with limited use over 85F, and cyclists usage peaked at 85F with limited usage over 91F. Temperatures over 90 are becoming more frequent in the state - **in 2020 there were 30 days with average temperature over 90 degrees**, this will continue to increase. Less usage of the trail limits the trail's ability to act as a critical recreation, wellbeing, and community building facility, as well as encourages users to choose cars over zero-carbon active transport.

- **Invasive Species and Infectious Disease** - As average temperature rises, so does the population of mosquitos and ticks. Mosquitos are particularly prevalent near bodies of water and marshland and ticks are prevalent in woodland - both of these habitats are reflected in the landscapes around the trail. Therefore, as the temperature warms, so does the risk of infectious diseases - like lyme disease - to those using the trail. Additionally, as the weather changes more generally, native plants are more likely to struggle as the niche they have adapted to alters. This provides a disturbed habitat for invasive species to capitalise on - and allows them to take over more easily than they would have previously. Invasive species, such as Mugwort, already pose an issue across our trail, with the vegetation needing to be cut back at least once a year.

Asphalt damaged by the heat.

Sea Level Rise

The Long Island Sound has been rising at a rate of 3mm/yr since 1970, and many areas of the Connecticut coastline are in FEMA designated flood zones that are predicted to be impacted by 1 foot or 20 inches of sea level rise. Sea level rise poses risks particularly for coastal trails where there is increased risk of flooding, or at worst, permanent inundation which makes the trails impassable. Additionally, rising sea level is likely to damage marshlands and the surrounding ecosystems our trails run through due to salt water intrusion.

Various sections of the proposed Shoreline Greenway Trail face significant flood risk due to sea level rise, with some specific pinch points where the sea level rise impacts are likely to be very severe. The sea level rise and flood risk of each section is as follows:

- **New Haven**: The trail section that runs along the New Haven harbour is not predicted to be inundated at 1 foot or 20 inches of sea level rise. However, the section that runs along Tweed airport towards East Haven is seen to be at significant risk with either sea level rise scenario.

- **East Haven:** The high risk flood zone of East Haven covers the majority of the Shoreline Greenway Trail in the town. For example, Coe Avenue towards the beach where the most recent section of on-road trail has been built is described by the Town of East Haven as a 'flood risk area.' An area at higher risk is that of Brazos Road and Fairview Road that run through the marshlands in the west of the town. This region is where a potential route for the trail may pass through - but it has been recommended by the Southern Connecticut Regional Council of Governments that at least one of these roads should be removed for improved marsh health because of the risk from sea level rise.

- **Branford:** There are several areas that are at high flood risk due to sea level rise in Branford. This includes Meadow Street in downtown Branford, as well as Tabor Drive where the road floods frequently enough that the town has decided, in the long-term, it cannot be saved. Additionally, the section of Route 146 that travels through the marshland between Branford and Guilford, which includes part of the Shoreline Greenway trail, is at high risk due to sea level rise and salt water inundation. For existing trail, the trolley trail section that passes over marshland is at high risk of flooding, and at 1 foot or 20 inches of sea level rise will face partial inundation.

- **Guilford:** Within Guilford, the trail primarily follows Route 146 and Route 1. Generally, much of Guilford south of the town green is at risk in a future that combines sea level rise and large storms. However, some areas of specific concern include: the bridge over the west river in Guilford and the section where Route 146 crosses a tidal creek at Soundview Road/Goose Lane.

- **Madison**: Either 1 foot or 20 inches of sea level rise is unlikely to inundate the existing trail in Madison, but the higher sea level is likely to compromise the marsh and can lead to high risk of flooding from storm surge

Wildfire

Wildfire is one of the lowest likelihood risks facing the trail currently, however, as wildfire becomes more prevalent in Connecticut it is important to consider. In fact, **Connecticut had four times more wildfire instances in 2024 than usual,** including one at Rocky Neck State Park which faced brush fires again in April 2025.

It's important to be diligent to wildfire, especially on our existing wooded trails. Even small bush fires can make areas of trail impassable and cause negative health impacts for the local community. Of course, larger bush fires can get out of control and significantly damage local ecosystems, the trail infrastructure and, in the worst cases, homes and businesses.

Defining Resiliency on the Shoreline Greenway Trail

The particulars of resilience are different from place to place, because climate change impacts are not homogenous. Indeed, from town to town along the Connecticut coast the degree of adaptation that will be needed to become resilient to climate change differs. In some contexts adaptation needs can change street by street. Therefore, as well as the overall definition of resilience, it's crucial to understand what our definition of resilience is for the Shoreline Greenway Trail specifically.

For the trail our definition is made up of these three parts:

1) In light of our changing climate, the trail **must remain 'a better way from here to there' far into the future** and still be usable as our summers get hotter and rainfall more intense.

2) The trail must be able **to bounce back and quickly recover** from extreme acute events, such as hurricanes and storm surges.

3) The trail needs to act as an **important piece of infrastructure** that facilitates the social, health and community resilience of the shoreline.

Making Existing Sections Resilient

Maintenance

Crucial to any infrastructure's ongoing resilience is its maintenance plan. The Shoreline Greenway Trail already has primary maintenance plans in place for its three sections of existing trail:

- **Madison**: Managed by Perry Rianhard, this section of trail gets consistent maintenance to both clear encroaching vegetation and repair the trail surface or boardwalk where needed. Support from the state is provided where needed - i.e. removal of large vegetation. A yearly maintenance budget is applied.

- **East Haven:** Maintenance is undertaken throughout the year with the support of groups like the boy scouts and the trail's high school interns. A yearly maintenance budget is applied.

- **Branford:** The sections of the Tabor Trail, Birch Road Trail and Trolley trail are maintained by Branford town - and so we are not primarily responsibile for the trail's maintenance. However, we do undertake some maintenance sessions related to overgrown vegetation.

Indeed, maintenance is crucial for the trail to remain usable and provides the 'eyes on the ground' to ensure issues are fixed or planned for before they become significant. Maintenance in this instance falls into three main categories:

- **Repairing the trail surface**: the trail surface can become damaged for many reasons. On a soft surface trail, which reflects most of the existing trail, heavy rain and high usage leads to erosion. On a hard trail, long stretches of hot weather can deform the asphalt surface and tree roots and heavy rain can lead to cracks and pot holes. Soft surface trails are more prone to erosion, and therefore require more maintenance of the trail surface. This can look like: filling holes, replacing gravel surface and rerouting water. Early maintenance such as this prevents larger resurfacing efforts from being needed in the future.

- **Planning for acute events**: Maintenance should be designed so that there is a plan after the occurrence of an acute climatic event such as a storm or hurricane. This can look like, visiting the trail soon after to ascertain if any obstructions - such as fallen trees - need to be removed and if there is any significant surface damage that should be repaired quickly to reduce knock on impacts.

- **Removing invasive vegetation:** As vegetation grows alongside trails it is important that it is cut back to ensure the trail remains passable. This is noted as a particular issue on both the Madison and East Haven trail sections - in Madison the main issues are the invasive Mugwort and Tree of Heaven. In fact, as our climate warms and ecosystems are put under stress, invasive species are likely to become more prevalent in Connecticut. Therefore, it's important to keep on top of, and remove, invasive species along the trail to not only benefit users but also help maintain the health and resiliency of the surrounding trail ecosystem. Finally, as the average temperature increases, ticks are likely to become more prevalent in Connecticut. In light of this, keeping vegetation off the path reduces tick encounter and risk of bites and possible infection.

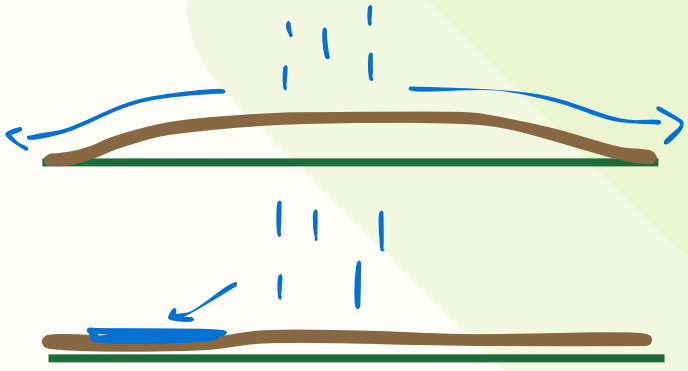
Improving the Trail Surface

Although large-scale redevelopment of existing trail is unrealistic due to financial and practical constraints, some changes can be made to improve the resilience of the trail surface itself.

On a **soft-surface gravel trail** like that in Madison and East Haven, the most significant threat is water. Both the pooling of water in puddles and the downwards movement of water during heavy rain causes significant erosion to the trail.

Alongside regular maintenance to fill holes and clear debris, there are several steps that can be taken to improve the trail surface and reduce the risk faced by the heavy rainfall we're already facing in Connecticut due to climate change:

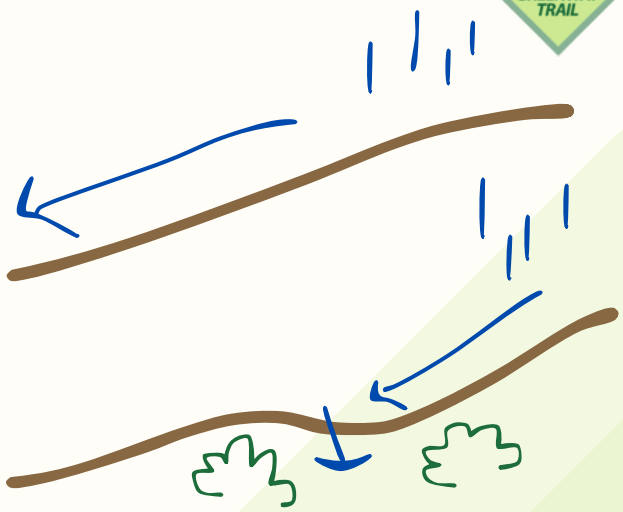
- **Crowning:** to reduce puddling on soft surface trails that leads to water penetrating in the centre and causing erosion, it's recommended the trail should be 'crowned.' The trail should be outsloped by 2% - meaning there is a slight gradient with the centre higher than the edges. This allows water to naturally flow off the trail into the surrounding vegetation. However, no more than 2% is recommended if the trail is to remain accessible for wheelchair users. There are currently plans to crown much of the existing trail in Madison in Fall 2025, but this could be applied to much of our soft surface trail in East Haven too.



Above: Crowned Trail allowing water to run off the trail.
Below: Flat trail leads to water pooling that invites further damage and erosion.

- **Regrading:** in general, the lower the gradient of the trail the less it will suffer from erosion due to rainfall. Therefore, **it is recommended that soft-surface gravel trails do not exceed a 5% grade**. Some regrading is planned for sections of the Madison trail in Fall 2025 to reduce the impact from water run-off. Overall, it's recommended that where trails cannot be flat, the grade should reverse - i.e. climb and then descend - every 20 to 50 ft.

- **Grade dips and Water Bars:** on steep sections that cannot be regraded - for example the steep section of the East Haven trail near Short Beach Road - grade dips or water bars can be used to reduce the flow of water and prevent sediment from being carried by sheet flow. Grade dips are perpendicular dips built into the trail that channel water. They are easy to maintain and do not interfere significantly with trail usage. Where grade dips are not possible, water bars can be used. Water bars have been the traditional method for diverting water off the trail and consists of a wooden beam placed perpendicular across the trail surface. They are cheap to install, but are only recommended where grade dips are not possible. This is because they require frequent maintenance when debris build up behind them. Additionally, if water bars are going to be used they should only be applied to sections that by their existing grade are not accessible - as they cause an obstruction for wheelchair users.



Above: Without grade dip, sheet flow can continue, gathering speed and momentum. Below: A grade dip slows the flow, and channels the water off of the trail.

- **In trail drainage:** on sections where the trail is cutting into a steep slope, the cross slope of the trail should be as level as possible. This reduces the risk of the sheet flow from the overall slope of the land causing washouts on the trail. In cases where the erosion has become significant, in trail drainage can be used to channel the water so that it reduces the total damage to the trail. This can look like grade dips, as explained above, or harder solutions such as stone channels

On a **hard surface paved trail**, there is less than can be implemented after installation to improve the overall resilience. However, if the trail is in an area exposed to the sun with little shade, it can be recommended to add a heat reflective coating to the paved surface. This reduces the heat that is absorbed and then radiated by the trail - ultimately reducing the temperature for those using the trail. If possible, this could be applied to the paved section of the trail in Branford.

Adding Vegetation

Adjusting the trail surface is only the beginning. To support resiliency for the whole trail environment, vegetation can be used in a number of ways on both soft surface and hard surface trails. This includes:

- **Vegetation as drainage:** carefully placed plants and trees can play a big role in reducing the water damage to trails. Firstly, when creating drainage channels it's advised that the water is drained into a rain garden - a depression with deep rooted plants that are designed to absorb excess water. This prevents the channelled water causing more erosion in other locations. Secondly, vegetation can be strategically planted on the uphill side of a trail to absorb and slow the flow of water coming onto the trail. Rain gardens such as these are most appropriate for trails not in a woodland or marshland environment.

- **Vegetation as shading:** as it gets hotter, trails without proper shading will see much lower usage during the height of summer. Adding trees can significantly reduce the temperature on the trail through a process of evapotranspiration - prolonging the trail's usage throughout the summer. Reducing the UV exposure to an asphalt surface also increases its longevity - meaning less resources are needed to restore or replace the trail surface

- **Planting Native Plants:** along the Shoreline Greenway Trail, we have an ongoing issue in our woodland sections of invasives becoming prolific and overtaking the trail. For the longer term, invasive plants can be removed through a combination of mechanical and chemical processes. After their removal, it's recommended to repopulate the area with native plants - keeping on top of weeding to allow the native plants to establish themselves. By introducing native plants that don't spread as aggressively, it can reduce the amount of vegetation management needed on the trail, and can bring a wider host of benefits as it strengthens the wider ecosystem and supports pollinators. This is an involved project, needing frequent, diligent efforts to keep on top of invasive growth, particularly in the first few years of restoration. Therefore, it's recommended primarily in distinctly 'problem' areas that are easily accessible and at a lower risk of invasives repopulating the area.

- **Absorbing CO2:** adding plants to currently non-forested areas provides an opportunity for the trail to not only divert carbon emissions through the use of non-fossil fuel transport but also absorb more carbon emissions from the atmosphere. Additionally, placing vegetation such as trees between a trail and a road reduces the air and noise pollution that reaches trail users from the cars - improving the air quality and experience of the trail.

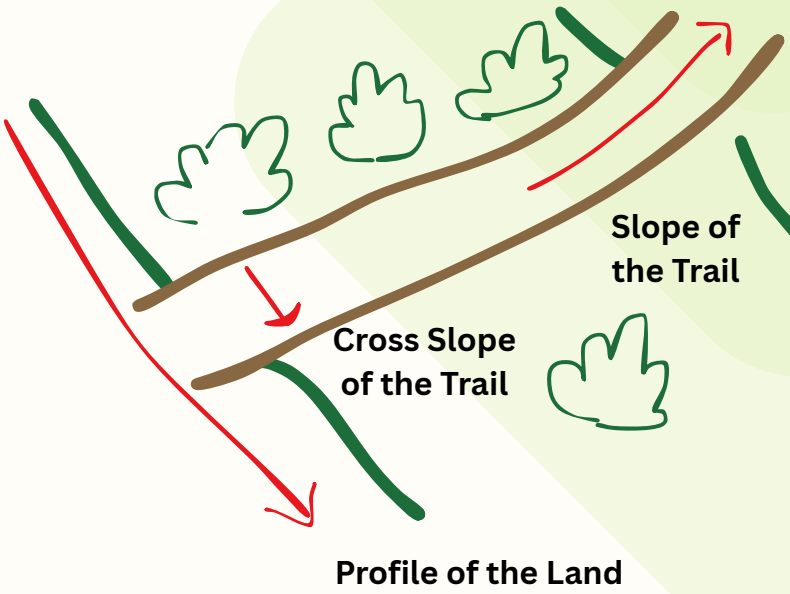
Designing new sections to be Resilient

Heavy Rain

As we have seen, heavy rain is one of the hazards that most commonly faces the Shoreline Greenway Trail, causing erosion and localised flooding. When designing new trails there are several factors that should be considered:

Trail Gradient - When designing new trails two elements of gradient will be crucial to designing a resilient trail. The first is the slope of the trail itself, i.e. the gradient parallel to the trail direction, and the second is the cross slope of the trail, i.e. the gradient of the trail and its surrounding terrain perpendicular to the trail direction.

- **Slope of the Trail**: In general, it's recommended that for accessibility and maintenance that the gradient of a trail does not exceed 10%. However, particularly on soft-surface trails it is recommended that the grade does not exceed 5%. Additionally, it's recommended that there should be trail reversals - i.e. a change in gradient - every 20 to 50 ft. as the longer a slope, the more severe erosion will be as the more energy sheet flow of rain has. Part of this is designing in 'grade dips' which is explained in depth in the section above.
- **Cross Slope:** In the first instance, it's important to be aware of the profile of the land the trail is cutting into, as if the trail is cut perpendicular into a steep slope it is likely to be subject to erosion from sheet flow off of the larger slope. To combat this, the trail itself should be as level as possible, with a slight crown in the centre to prevent water pooling at the trail's centre. In fact, it's recommended that the crown of a trail, regardless of wider trail context, should be anywhere from 1% to 5% - however a grade of 2% is ideal if the trail is narrow in order to make it as accessible as possible for all users. This is most important for soft surface trails, but is also important for hard-surface trails as pooling can still cause damage, or lead to erosion of the trail edge as users navigate around puddles.



Above: Illustration demonstrating different gradients that must be considered when designing a trail.

Trail Surface - There are many factors to take into account when choosing the surface of a trail but when you have heavy rain and flood risk as a priority, we recommend the following:

- **Soft Surface Trails:** Soft surface trails are generally preferred in natural areas as they are more suitable for their surroundings, and enhance connecting with nature. However, they are more vulnerable to issues such as erosion and flooding. Therefore, it's recommended that not only is the grade controlled (see above) but also that the trail surface is a heavier gravel. This is because a larger gravel is less prone to erosion compared to smaller sand-like particles. Additionally, the trail should be well-compacted and well-maintained to reduce erosion in the first instance. Due to the risk of erosion, it's recommended that soft surface trails are not used in areas that frequently flood, and a hard surface should be considered instead.

- **Hard Surface Trails:** When it comes to longer-distance, heavily used trails, hard surface trails are preferred as they are much less susceptible to erosion from both rain and usage. Traditionally used materials such as concrete or asphalt are hard wearing and resilient, particularly to flooding. However, there is an opportunity for trail designs to use permeable paving. For example **porous asphalt** has the benefits of a hard surface, with the lower maintenance cost, whilst allowing rain water to drain through the surface - reducing the risk of flood due to impervious surfaces.

Above: Example of a hard surface trail on the Tabor Trail section of the SGT.
Left: Example of a soft surface trail on the East Haven section of the SGT.

Drainage Infrastructure - Alongside designing with an appropriate grade and surface, it's sometimes crucial to consider drainage infrastructure on the trail to channel and divert rain water.

- **Cross Trail Drainage:** Particularly useful on hard-surface trails are opentop channels perpendicular to the trail, that allow for water to be carried across the trail with limited erosion. The water from these channels should be diverted into rain gardens or similar to avoid further erosion (more on this below).

- **Ditches and Turnouts:** More appropriate for soft surface trails, are ditches and turnouts that take water that has run off the trail - due to crowning - and redirects it so that it can percolate into the surrounding greenery or a specifically planted rain garden.

Vegetation for Drainage - Wherever you are designing drainage, or encouraging water to run off a trail, it's important to ensure there is vegetation that can soak up this excess water. In an already wooded area this is normally already provided - and should just be maintained - but if building in an open space or alongside a road, rain gardens or Sustainable Drainage systems (SuDs) should be implemented. These are strategically placed gardens, with deep rooted plants that are designed to absorb excess water, reduce surface flooding and filter out pollutants.

By implementing these gardens it not only reduces the risk of the trail becoming impassable, but allows the trail to act as a wider piece of resilience infrastructure as it reduces flooding risk on the road and reduces the negative impact on local ecosystems of road run-off.

Example of a Sustainable Urban Drainage System in New Haven. (not on SGT.)

Storms and Hurricanes

As Connecticut becomes increasingly at risk due to hurricanes and storms, it's important to design with them in mind. Many of the adaptations for heavy rain help build resilience to hurricane and storms, but there are some additional elements to consider:

- **Water Crossings:** If designing a boardwalk, bridge or culvert over a water crossing or marshland, it should be planned to withstand a severe 100-year storm event. Historic resiliency standards are increasingly becoming unfit for purpose, even in relatively small-scale storms. For example, if a bridge or boardwalk is built to bridge the gap between the two halves of Cosey Beach Avenue, it ideally should be robust enough to withstand flooding events like that we saw in super storm Sandy and Irene. Tactics such as anchoring and materials that allow water to flow through them can improve bridge or boardwalk resilience. Where this level of construction is not possible, alternative routes should be considered.

- **Extreme Weather Planning:** As there is little that can be done to mitigate the worst of storm surge and high winds in hurricanes or large storms, it's important to have a process for checking and repairing the trail after a storm. Therefore, a procedure should be put into place to ensure trails are checked and impassable obstructions are removed or repaired as quickly as possible after a storm event.

Heat Waves

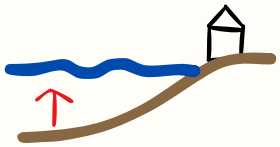
To protect both the trail itself, and its users, there are a number of steps that can be taken to mitigate the impacts of extreme heat:

- **Introduction of Shade:** As our temperature increases, it's **recommended that tree coverage on trails is at least 50%, with 75% the ideal**. Tree coverage shades the trail, reducing damage to the trail itself due to high temperatures and UV, whilst also making the ambient temperature cooler, encouraging better trail usage. Therefore, all trails should be planned to include as much shade coverage as possible. This is particularly important when the trail goes through urban areas - such as the New Haven trail section - as trees on trails can be a crucial player in reducing the effect of the Urban Heat Island. However, it's crucial that tree choice is carefully considered and implemented. Trees should be hard wearing, and well maintained to avoid tree dieback due to hot weather and drought.

- **Consider the trail surface:** When using hard surfaces, they are not made equally when it comes to heat. Generally, it's recommended that concrete is better than asphalt for exposed portions of trail. This is because concrete is lighter in colour, so absorbs less heat, and is less impacted by prolonged warmed weather. To take it a step further, there are also opportunities to treat the trail surface with reflective, anti-UV paints or treatments that reduce the long-term damage to the trail and the amount of heat absorbed.

- **Design for hot weather:** Recreating on the trail in hot weather will always be more tiresome than cooler weather - even when the path is well shaded. This means it's useful to provide shaded benches and water fountains where possible. This allows for trail users to rest, and use the trail safely. Indeed, providing more opportunities for rest not only makes the trail more accessible, but also can allow for moments of community building as people cross at common resting spots.

Sea Level Rise



In many ways, sea level rise is at once the hardest and easiest of the climatic threats to design for.

To begin, it's recommended that when designing any trail section, **the team consults a sea level rise and future storm surge map such as this map published by CIRCA**. Much of the Shoreline Greenway Trail route is at risk of flooding, but the vast majority is not predicted to be underwater due to sea level rise. Regardless, it's good practice to design the trail so that it avoids areas that are likely to be inundated at 20 inches of sea level rise - the projected level by 2050. This avoids needing to redesign, or move, the trail if it's in an area that repeatedly floods in the future.

However, **sea level rise can present opportunities for trail development**. On a privatised and expensive coastline, like the Connecticut coast, sometimes land that is increasingly at risk from sea level rise and can become available for trail building.

For example, roadways or permanent homes can often not persist in areas that frequently become inundated with water or routinely flood. On the other hand, trails - especially those for recreation - can be built in these areas. For example, trails can be built at a flood-resilient standard and act as part of a wider natural flood plain that can have the dual purpose of offering outdoor recreation and water absorption to reduce flood risk in the rest of the community. Or, even better, when roads are decommissioned there can be opportunities for raised trail boardwalks to be built on their foundations, extending trail infrastructure as the community more broadly adapts.

Wildfire

Wildfires are generally lower risk in Connecticut compared to other areas of the country, however, they are increasing in their frequency and severity.

Along the Shoreline Greenway Trail, there is limited applicability of some common wildfire prevention techniques - such as using the trail as a fire break - due to the relatively small scale of the wooded areas the trail passes through. If the wildfire risk becomes more severe, there is an opportunity to clear out under growth in wooded areas near the trail to limit the ability for fire to spread across the trail. As the risk currently stands, it is most useful to promote wildfire risk and awareness on the trail, giving trail users the information they need to understand when they should be vigilant for wildfires and report them to the appropriate state authorities.

Positioning the Trail as Resiliency Infrastructure

As our climate changes, it's not only important that the Shoreline Greenway Trail is designed to withstand physical impacts but also provides an environment that helps local communities remain resilient. In fact, the trail can help the coastal community be resilient in the following ways:

- **Building Community:** A variety of studies have demonstrated that stronger social connections and trust within communities leads to greater climate resilience outcomes. Public infrastructure like parks, squares, and trails provide spaces and opportunities for community members to either meet one another or actively volunteer together. It provides a local focal point, a place to feel proud of and invested in. This strengthens place-based bonds to a town, and encourage users to invest more time into the people and places in its vicinity. This can then have a benefit for the economic, aesthetic and social fabric of the town - making the town stronger and more resilient to all sorts of change. Particularly for climate change, investment in the place you are and strong relationships between community members opens more opportunities for real collaboration that allows for better climate adaptation planning and implementation.

- **Connection to Nature:** Having a shoreline trail that follows a coastal route through areas of nature provides an invaluable space for locals to connect with the ocean, marshlands and forests on their doorstep. This time spent in nature leads to the public having a deeper connection with the wildlife around them, which in turn promotes them to make more environmentally conscious choices. Maintaining and building the trail is therefore an important tool for encouraging climate and conservation actions amongst the residents of New Haven County.

- **Healthier Communities:** Spending time on trails promotes better physical and mental health outcomes for users. We already saw how important trails were for wellbeing in the COVID pandemic, with the Shoreline Greenway Trail seeing increased use from 2020 onwards. As the impacts from climate change become more evident, time on trails can help improve cardiovascular and respiratory health and combat the negative impact rising temperatures will have on these critical systems.

The trail already provides all of these benefits, but we do not capitalise on them. Therefore, it's important we do the following:

- **Publicise the trail's good work:** Our social media, signage, publications and events should celebrate the wider resiliency benefits it provides. Helping people to understand just what the trail provides can increase interest, momentum and even funding behind the organisation's mission and campaign

.

- **Enhance these benefits:** We have already begun to do this, but we can enhance them further through a number of means. For example, holding volunteer events, providing seating and gathering places to encourage connection, increasing the trail's accessibility, and education programmes that facilitate a deeper engagement with the nature surrounding the trail.

- **Make connections:** Part of the resiliency benefits the trail provides are due to its interconnectedness with the communities and town centres it passes through. By getting as many local people and businesses involved as possible we can increase the trail's ability to not only provide users with exactly what they need, but also link up trail users with what's happening in their local area.

Action Points for a Resilient Trail

Throughout this report, we've offered a variety of solutions and approaches that can be embraced to design and maintain a trail that is resilient. However, what is the priority? **What should the Shoreline Greenway Trail do over the next year or two?**

Make sure resiliency is at the forefront of all current plans

Whenever plans are being made to maintain, improve or design new sections of trail, the organisation should always ask the question: **will this promote a sustainable and resilient trail both now and in the future?**

If the answer is no, this report offers a wide number of suggestions to guide plans so that the answer can be changed to yes. For example, this could look like asking those who draw up the technical design of new trail sections to make resilience a top priority, or when events are being held ensuring there's a mention of our changing climate, and building resilience to it, where possible.

Design proposals for Resiliency Funding

One opportunity that the trail should look into as it makes resiliency a priority is finding funding sources that are specifically designed to build climate change adaptation infrastructure or maintain recreational trails in the face of climactic threats. And more generally, resiliency concerns can be used to improve or enhance grants that are focused more specifically on trail maintenance.

Resiliency Funding Opportunities

- Funding Database – Resilience Hub - Long Island Sound Study's funding data base, which often includes resiliency funds. Specifically look out for: Long Island Sound Resiliency Support Program that advances climate resiliency projects throughout the CT and Long Island coast.
- DEEP Climate Resilience Fund - Not currently active, but plans to extend award after initial funding round in 2023.
- Trails Capacity Program - American Trails, designed specifically for trail maintenance.
- PROTECT Grant - A federal funding grant for resiliency focused transportation projects - including trails. One more year of the funding cycle in 2026. Learn more here.

More General Funding Opportunities

- Connecticut Regional Trails Funding - Trail design, planning and creation.
- Rails to Trails Grants - Maintenance and trail creation.
- Trails Trust Grant - Maintenance and trail creation.

Use Trail Events to Educate about Resiliency

When hosting a trail walk, ride or other information session, it's a good moment to talk about resiliency with trail users. 'Resiliency' as a concept may sound intimidating, but these events offer an opportunity to **introduce the simplicity of resilience and link it to the local environment.** When someone hears 'resiliency' they may think of responding after a hurricane - which is true, but it's useful to stress how mundane much resiliency is.

As we've shown in this report, it's about ensuring trail surface can withstand heavy rain, or trail users can be in shade when the weather is hot. Demonstrating this reality can help users relate to and understand what needs to be done to adapt to climate change on a smaller, local scale. In turn this can make resiliency seem not only much more achievable, but also encourages them to see opportunities for resiliency in their own jobs, homes and local communities.

Look for Opportunities

For our trail on the Connecticut coast, the impact of climate change will mostly be negative as we've seen throughout this report. However, as a next step for the trail, it can be useful to look at the areas of our coastline facing the most risks and consider possible opportunities for trail development.

For example:

- **Trails can be designed to flood regularly.** In fact, they can be part of coastal parks or marshland restoration projects that are designed to absorb water run off from heavy rain and reduce storm surge impacts. As sea level rise increases, its likely that more parks like this will be commissioned to manage flood risk.

- **Trails can be built as elevated boardwalks, using abandonned asphalt roads as foundations.** A small number of side roads will be deemed too difficult to maintain and not possible to raise in line with sea level and storm risk. Therefore they will be abandoned. This allows trails to be built without infringing on private property, and still providing connections for emergency supplies and everyday transportation.

- **When sections are redesigned due to climate risk, sidewalks or bike lanes can be included in the plans.**

Further Reading

This report aims to act as a first step for the Shoreline Greenway Trail on their journey to becoming climate resilient. It offers some preliminary guidance for adapting the trail - both current and future - to climate change and outlines key questions and considerations to be incorporated as part of resilient trail management.

In the references there are a wide range of resources, but here are some stand out pieces of general guidance on resilient trails across the US:

- **Trails and Resilience: Review of the Role of Trails in Climate Resilience and Emergency Response** (US Department of Transportation)
- **Trails as resilient Infrastructure Guidebook** (US Department of Transportation)
- **Trails and Climate Resilience** (Rails to Trails)

References

Print References

American Trails Staff (2024) 'Why Trails Matter: Trails Build Community' American Trails https://www.americantrails.org/resources/trails-are-inclusive

Bachensky, L. (2019) 'What You Need to Know About Building Trails with Crushed Fines.' American Trails https://www.americantrails.org/resources/building-crusher-fines-trails

Bike it or Hike it (last updated, 31st May 2025) 'Shoreline Greenway Trail' Bike it or Hike it. https://bikeitorhikeit.org/shoreline_greenway_trail.htm

Carmen, E. et al. (2022) 'Building community resilience in a context of climate change: The role of social capital' Ambio 51

Ciabotti, J et al. (2023) Trails as resilient Infrastructure Guidebook US Department of Transportation

CIRCA (2023) Resilient Branford: Final Report https://draft-resilientconnecticut.media.uconn.edu/wp-content/uploads/sites/3830/2024/06/CIRCA-Resilient-Meadow-Street_Final-Report_20230929.pdf

CIRCA (2019) Connecticut Physical Climate Science Assessment Report

CIRCA (N//A) 'Connecticut Sea Level Rise and Storm Surge Viewer' CIRCA https://circa.uconn.edu/sea-level-rise-and-storm-surge-viewer/

Connecticut DEEP (2025) 'How Climate Change Affects Forests' CT Government https://portal.ct.gov/deep/forestry/climate-change/how-climate-change-impacts-forests#Invasive%20Species

Connecticut Department of Transportation (2025) Route 146 Corridor Management Plan

DeVille, N. V., Tomasso, L. P., Stoddard, O. P., Wilt, G. E., Horton, T. H., Wolf, K. L., Brymer, E., Kahn, P. H., Jr, & James, P. (2021) 'Time Spent in Nature Is Associated with Increased Pro-Environmental Attitudes and Behaviors.' International journal of environmental research and public health, 18

Gais, K. (2025) 'Brush fires ignite at Rocky Neck State Park' NBS Connecticut https://www.nbcconnecticut.com/news/local/brush-fires-ignite-rocky-neck-state-park/3549204/

Galle, N & Dalley, J. (2024) 'How trees can help keep us healthy and active in hot weather' American Forests https://americanforests.medium.com/how-trees-can-help-keep-us-healthy-and-active-in-hot-weather-d001a3cebeee

Georgiou, A. (2025, July 17th) 'Nor'easters have become 20% more destructive in the last 80 years' Live Science https://www.livescience.com/planet-earth/climate-change/noreasters-have-become-20-percent-more-destructive-in-the-last-80-years-scientists-warn

IPCC (2022) 'Summary for Policymakers' [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (ed.) Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

Koehler, R. and Sowers, J. (2018) 'Trails Assessment and Recommendations for Management' American Trails https://www.americantrails.org/resources/trails-assessment-and-recommendations-for-management

MacDonald, S. (2018) 'Porous asphalt shows advantages for trail surfacing' American Trails https://www.americantrails.org/resources/porous-asphalt-shows-advantages-for-trail-surfacing

Mendelsohn, R., Rajaoberison, A., Yoo, J. (2020) 'A Coastal Resilience Analysis of a Heterogeneous Landscape' Journal of Environmental Protection vol. 11

Metzger, C. (2025) 'CT had five times more wildfires than usual in 2024. Officials warn this could be the new normal' CT Insider https://www.ctinsider.com/recordjournal/article/connecticut-wildfires-climate-change-floods-20024877.php

New Hampshire State Government (2017) Best Management Practices For Erosion Control During Trail Maintenance and Construction https://www.nhstateparks.org/getmedia/3c45de00-e174-4df0-b678-4670b254290d/Best-Management-Practices-For-Erosion-Control-During-Trail-Maintenance-and-Construction.pdf

Rails to Trails (2024) 'Trails and Climate Resilience' Rails to Trails https://www.railstotrails.org/trail-building-toolbox/trails-and-climate-resilience/

Rice, M. B., Thurston, G. D., Balmes, J. R., & Pinkerton, K. E. (2014). 'Climate change. A global threat to cardiopulmonary health.' American journal of respiratory and critical care medicine, 189

Ritchie, M & Tait, J (2016) 'Storm Impacts Research: Using SENCER-Model Courses to Address Policy' Science Education and Civic Engagement

Shoreline Greenway Trail (2011) 'Volunteers cleared Branford Tabor trail – rescheduled First Saturday Walk to Nov. 5' Shoreline Greenway Trail https://shorelinegreenwaytrail.org/help-with-trail-clean-up-after-hurricane-irene/

Spalding, H.C., Nadkarni, S., Bekker, C., Collado-Nicol, D. (2021). 'New England Coastal Cities: The Struggle for a Resilient Future.' In: Conrad, K. (eds) From Hurricanes to Epidemics. Global Perspectives on Health Geography. Springer, Cham

Stark, S. (2020) 'Trails Forecast: Resiliency and Repair' Rails to Trails

Stroud, S. (2020) 'Trails Enhance Resiliency' Trail Impacts Publication Series

Town of East Haven (2019) *Town Of East Haven Plan Of Conservation And Development 2019 Update*

Tracy, C (2020) 'Trails Build Community' *Trail Impacts Publication Series* https://media.clear.uconn.edu/projects/ct_trail_census/docs/Trail-Impact-Series_Community.pdf

US. Department of Transportation Volpe Center (2023) *Trails and Resilience: Review of the Role of Trails in Climate Resilience and Emergency Response*

We Conserve PA (2024) 'Trail Design and Maintenance' *We Conserve PA Library* https://library.weconservepa.org/stewardship-handbook/231-trail-design-and-maintenance

Whelchel, A. W., E. Livshits, M. Fulda, M. Sloan, C. Rappa, K. Deneault (2017) *The Southern Connecticut Regional Framework for Coastal Resilience Final Report*. South Central Regional Council of Governments.

Interviews and Correspondance

Dan Amstutz - VHB - Route 146 Plan - zoom interview

Abigail Winter - CT DEEP - Long Island Sound Study - zoom interview

Perry Rianhard - Shoreline Greenway Trail - maintenance on Madison trail section - in person interview

Barbara Brow - Shoreline Greenway Trail - previous East Haven town chair - in person interview

Matthew Lieber - Shoreline Greenway Trail - East Haven town chair - in person interview

Judy Miller - Shoreline Greenway Trail - Branford town co-chair - in person interview

Virginia Raff - Shoreline Greenway Trail - Madison town co-chair - in person interview

Barbara Yaeger - Aris Land Studio - Designer of new Hammonasset section - email correspondance

Acknowledgements

Report Writer and Designer: Daisy Everingham - Shoreline Greenway Trail Summer Intern 2025

This report was made possible due to the generous funding of the Greater New Haven Green Fund.

In addition, I'd like to whole-heartedly thank all of the Shoreline Greenway Trail team for their support and insight that made the creation of this report possible.