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Pedestrian Bridge Design in Lancaster, MA

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Sponsored by: Lancaster Friends of the Nashua River

March 6, 2015
Pedestrian Bridge Design in Lancaster, MA

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the degree of Bachelor of Science

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March 6, 2015

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Abstract

Recreation areas improve community members’ physical and psychological health, increase property values, and provide a host of ecological services that benefit the environment. This project, sponsored by the Lancaster Friends of the Nashua River, explored ways of improving public access to the Cook Conservation Area in Lancaster, Massachusetts.

As a result of our investigation into soil conditions, aesthetic choices, and structural stability, we recommend the construction of new pedestrian bridges. Results of our work include cost estimates, permitting forms, and models of the proposed bridges. These materials will help improve trail user satisfaction and contribute to the success of the Cook Conservation Area as an important community resource for the town of Lancaster.
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Authorship

Sections of this report were written individually and peer edited as a group. While the writing process was collaborative, team members took responsibility for the following sections:

- Adam Carrier focused on agencies involved with rivers, ADA requirements, and topography.
- Johnpatrick Connors focused on the history of Lancaster, biodiversity, erosion control, structural design, and modeling.
- Hannah Lee focused on riparian ecosystems, the history of bridges, assessing visitor priorities, cost estimation, and permitting.
- Jeremy Soderholm focused on the benefits of rivers, assessing local criteria for bridge structural design, soils analysis, structural design, and modeling.
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Executive Summary

Throughout history, rivers and the various plants and animals they sustain have played a major role in supporting community development and human life. The use of rivers for drinking water, food, transportation, and energy has been vital to the growth and prosperity of civilization. Yet, in the past two centuries a lack of oversight and an overdependence on rivers has resulted in serious environmental consequences. Over time, many American rivers became heavily polluted due to the discharge of industrial effluents while other rivers experienced an unnatural diversion as a result of manmade structures. The despoliation of rivers and their use as waste receptors largely went unchallenged until the late twentieth century, when concerned citizens enacted river campaigns to improve river health across the United States. Activists lobbied for the restoration of rivers to their natural state, free of waste, and full of wildlife. One of the great success stories of this movement is the Nashua River.

By the 1960’s the Nashua River was one of the most polluted waterways in the United States. The river was teeming with raw sewage, paper mill pulp, and a host of organic toxins from industrial activities occurring upstream. Through the efforts of many dedicated and hardworking citizens, the Nashua River now runs clean and is full of wildlife [Bolling (1994), xvii]. The Lancaster Friends of the Nashua River is a new community group, established just four years ago, that now works to protect the river. This group engaged our project team to increase accessibility to the trail network within the Cook Conservation Area, a town-owned trail network that lines a stretch of the north Nashua River in Lancaster, Massachusetts.

To achieve the goal of improving accessibility to this area, our group engaged in a wide range of activities. Through a survey administered to Cook Conservation Area trail users, our group found that replacing current bridges in the Cook Conservation Area would greatly benefit
trail users. The team began the bridge design process by reviewing the permits and specifications that govern their design. We examined the challenges involved with wetlands construction by working closely with town officials and researching the permitting process. Repeated site visits [See Appendix H], consultations with engineering professors, and our own experience confirmed that constructing new trail bridges was feasible. After feasibility was confirmed, the team used soil testing and classification to help design an appropriate foundation structure. To increase service life and provide adequate stability, our group established an erosion prevention mechanism designed to protect the bridge foundations and control erosion. Our project team examined bridges at other conservation areas to gain a sense for common material choices and structural configurations. Once a structural design was selected, our group calculated the loads that the bridge will experience associated with pedestrian, equestrian, and light utility vehicle use. The team performed a finite element analysis on the proposed design to determine required member sizes. Once the team confirmed the bridge member sizes and configurations, we created a three-dimensional models and construction drawings of the bridge designs. To gain a better understanding of how this project would receive approval for construction, we conducted a Notice of Intent presentation for the Lancaster Conservation Commission. This presentation provided our team with recommendations for achieving our project goals, revealed the steps required for project approval, and allowed our group to form recommendations for projects that future groups could complete.

From the survey of the Cook Conservation Area trail users, our group found that users significantly preferred the replacement of trail bridges as opposed to a handicap accessible picnic area, leading us to focus our efforts on designing replacement trail bridges. Upon examining the required bridge dimensions based on the American’s with Disabilities Act (ADA) standards, our
group found that it would be plausible to design a structure given the proposed bridge sites. To comply with the permitting process our group filled out and submitted a WPA 3 Notice of Intent Form and an Environmental Notification Form to the Lancaster Conservation Commission. From our soils analysis, we classified the soil at bridge site 1, the crossing of McGovern Brook approximately 0.5 miles along the Farnsworth Trail, as silty sand. Similarly, we classified the soil type at bridge site 2, the crossing of an intermittent stream a little less than 1.5 miles along the Farnsworth Trail, as poorly graded sand with silt. These two soil types have the same bearing capacity; therefore, our group designed one foundation to fit both sites. To avoid the use of a large concrete mass associated with traditional abutments, our team designed concrete columns and footings to support the bridges by using a 12” diameter Sonotube connected to a 28” by 28” concrete footing at each corner of the bridge. The supports will be embedded four feet below the top of the soil before the Sonotube and footing are filled with concrete and connected to the bridge. To protect against erosion, our group recommends the use of riprap and seeding. Our project team evaluated the performance both Trex and Southern Yellow Pine as decking material. Trex has a higher initial cost but a longer service life. However, after performing structural analysis, we found that Trex would provide insufficient strength given the intended use of the structures. This inadequacy forced us to specify standard pressure treated lumber. Our group recommends the use of pressure treated No.1 Southern Yellow Pine for all members of the bridge.

The Lancaster Conservation Commission provided several suggestions aimed at improving the likelihood of project approval. The most important of these suggestions was to create an erosion prevention plan for the construction phase which would mitigate silt sedimentation during bridge construction.
Overall, our group recommends the construction of new trail bridges to increase accessibility within the Cook Conservation Area. The new trail bridges will use Southern Yellow Pine to respect the natural beauty of the area. The bridges will make use of concrete columns and footings to minimize the amount of concrete used. Further improvements to the Conservation Area can be achieved in a number of ways, the most important and pressing of which is improving the parking area.

Our team began this project with the ultimate goal of improving access to the Nashua River. Throughout the project we were cognizant of the societal and environmental impacts of our work. Engaging the public through a survey and consulting public officials allowed us to achieve this goal. Participation in the Notice of Intent hearing provided insight from conservation experts and further strengthened the goal of our project. Overall, this project involved the design of a bridge structure that is sensitive to its surroundings and befitting of community needs. If implemented, our project will increase access within the Cook Conservation Area.
1.0 Introduction

Romantic river! on thy quiet breast,
While flashed the salmon with his lightning crest,
Not long ago the Indian’s thin canoe
Skimmed lightly as the shadow which it threw;
Not long ago, beside thy banks of green,
The night fire blazed and spread its dismal sheen.
- Rufus Dawes, 1830

A small survey box affixed to a trailhead sign has produced an outpouring of information on the Cook Conservation Area in Lancaster, Massachusetts. During the first three months after the survey box was installed, 22 trail users took time away from their recreation experience to report on their use of the land and comment on their desired improvements. This level of activity is both surprising and promising. The Cook Conservation Area contains a system of rudimentary nature trails which parallel one of the United States formerly most polluted waterways, the Nashua River. In the 1960s, the Nashua River would change color almost daily as industries upstream altered the levels and types of toxins discharged into the river. Today, the river flows clear due to a grassroots movement led by citizens that enlisted the help of local politicians to restore the river’s health and promise as a habitat and recreation platform.

As recently as two years ago, the Cook Conservation Area was closed to the public and residents of Lancaster were unable to enjoy the river, the wildlife, and the beauty of the land. A similar cleanup effort led by another group of concerned citizens called the Lancaster Friends of the Nashua River lobbied to reopen the conservation area and provide citizens the opportunity to engage in a wide range of recreation activities within the Cook Conservation Area.

To continue in this rich tradition of environmental stewardship, our aim as a project group was to improve access to the Cook Conservation Area. As a first step towards achieving
this goal, we surveyed trail users to understand the various uses of the trails and the desired improvements of those users. We selected improved stream crossings as an area in need of improvement that aligned with the technical expertise of this group and produced project deliverables including construction documents and educational material. We also explored the relationship between rivers and communities by researching the backgrounds and historical contexts of river and pedestrian bridge use in New England. Researching the history of bridges, land use, and the Nashua River along with surveys of trail users helped in creating access improvements that fit users’ needs and the natural aesthetics of the Cook Conservation Area. Furthermore, our engineering approach to increase accessibility to the area focused on creating a low cost, highly efficient, easy to construct, and environmentally responsible solution.

If implemented, our solution will increase access to the Nashua River and enhance the positive effects that this river has on the citizens of Lancaster. In a broader sense, this project is part of a larger goal, at the national level, to avoid the fragmentation of open space and create more publicly accessible recreation areas. As the environment is changing and population is increasing, it is becoming more important to improve the quality of recreation areas, especially those centered along rivers. Protected environmental areas provide citizens with countless physical and psychological benefits, which in turn result in increased awareness and protection of natural resources.
2.0 Social Context and Historical Background

Naturally occurring rivers have long encouraged settlement and buoyed civilization. Rivers provide transportation and resources, such as food, water, and power, to civilization. Unfortunately, as society’s reliance on rivers went unchecked, the despoliation of rivers became increasingly noticeable. Pollution caused by humans severely altered the health of rivers and the biological life they support. The habitats of many fish and other animals have been changed by settlement and structures, such as dams and poorly designed crossings, which altered the natural flow of rivers. In the 1960’s and the latter part of the twentieth century it became clear that the unregulated use of rivers needed to be changed. This realization led many people and organizations to dedicate their time and resources to protecting rivers from further damage [McCool (2012), 8-10]. Dedicated citizens and agencies worked tirelessly to preserve the habitats of animals and maintain the natural beauty of rivers for society’s enjoyment.

2.1 Maintaining and Enjoying Rivers

The pollution of rivers and deviation of their natural flow has a profound impact on animal habitats. Fish habitats can be drastically changed or completely destroyed by human negligence. Dams and poorly designed river crossings, such as the one shown in Figure 1, prevent fish from moving through rivers and watersheds. These man-made structures can prevent species of fish from reaching feeding areas, breeding grounds, or natural Coldwater habitats, which can lead to heat stress. Blockage of streams can also cause overpopulation of an area, which can leave fish susceptible to predators and vulnerable to other dangers. For example, many species of fish need to travel miles upstream in order to reach their natural spawning areas. If the flow of these streams and rivers have been blocked or changed due to dams or poorly designed river crossings, these species will not be able to reach their natural breeding grounds. Blockage
of breeding grounds will lead to a decrease in the fish population. In order to protect fish populations and the natural flow of rivers, engineers have developed more practical bridges and crossings [Singler and Graber (2005)]. Restricted movement along rivers and reduced oxygen content caused by organic pollutants can cause great harm to fish habitats and populations. In order to protect native fish species and other organisms that inhabit a river’s ecosystem, riparian communities need to employ careful design of river and stream crossings and need to reduce the pollution of rivers.

Fishing is one of the many popular and economically significant recreational activities done on rivers. In 2011, anglers in Massachusetts spent approximately 455 million dollars on fishing gear, permits, and fishing trip expenses. Approximately 105 million of these expenditures were for freshwater fishing, such as in rivers [U.S. Department of the Interior (2011); U.S. Fish and Wildlife Service (2011), 8]. Fishing helps to connect people with rivers. This connection in turn encourages people to get involved in the preservation and maintenance of rivers. If the fish population were adversely affected by pollution or other human influences then it would decrease the enjoyment that citizens derive from fishing.
Fishing is, of course, not the only activity that people can enjoy on or near rivers. Hiking, canoeing, biking, swimming, and simply enjoying the beauty of nature are just a few of the many activities that clean rivers promote. Unregulated and polluted rivers, however, do not provide the same enjoyment from these activities. Heavily polluted waters are not only unsafe to swim or wade in; they produce a foul odor and have an unsightly appearance. Polluted waters prohibit canoeing, swimming and make it far less enjoyable to walk along the banks of the river and enjoy the natural environment. Pollution of the Nashua River had such a negative affect that by the 1960’s, the water was viscous and changed color on a daily basis, as shown in Figure 2. Some members of the community facetiously suggested paving over the worst sections of it [Dymon (1990), 78]. The pollution changed the river from a place where people could go to enjoy nature to an eyesore that people wanted to forget. After an extensive effort to improve the river, citizens of Lancaster, Massachusetts and its surrounding towns can once again use this beautiful area to exercise and enjoy the beauty and serenity of the area.

Figure 2: The Nashua River in the 1960’s running brown, compared to its clean state in the 1980’s [Nashua River Watershed Association (2013)]
2.2 Social Benefits of Clean Rivers

Clean, healthy rivers help sustain human health, economic vitality, and ecosystem diversity. This section will discuss the social implications of river health.

2.2.1 Public Health

Healthy rivers are generally more attractive to hikers and exercisers. Improved vitality of rivers encourages the development of nature trails in order to provide easier access to the area. Trails encourage more people to exercise along the river and enjoy nature. The benefits of physical exercise have been extensively studied and documented. Physical activity, such as walking, can improve health by reducing the risk of dangerous health ailments, such as cancer and cardiovascular disease. The United States Center for Disease Control has recommended that every adult in the United States do at least 30 minutes of semi-vigorous exercise most or all days of the week [Prate, Pratt, and Blair (1995), 402-407]. River trails encourage people of all ages to exercise and can therefore help them reach this recommended daily exercise time. Walking is an easy and non-strenuous way to exercise and river trails allow people to walk while connecting with and enjoying the natural environment. Trails also give people an easy and safe place to walk. A study conducted in Missouri in 2000 found that 55.2% of people who used walking trails reported that the amount of walking they had done increased after trail use. This study also found that 36.5% of respondents had access to walking trails and that only 19.5% of respondents walked for at least 30 minutes, five or more times a week [Brownson (2000), 235]. Another study conducted in Lincoln, Nebraska found that every dollar invested in walking and biking trails led to a $2.94 decrease in health-care costs [Wang, et al. (2009)]. This development in turn leads people to exercise by making use of the trails. By creating more trails, more knowledge of

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trail areas, and more accessibility to trails, a larger number of people will be able to take advantage of these exercise areas.

2.2.2 Economy

The economic effects of greenways extend beyond recreation equipment expenses to include major impacts to real estate values. Multiple studies have found that trails and greenways have a positive impact on the value of nearby properties [Karadeniz (2008); Nadel (2005); Penna (2006)]. A 2006 study on the Minuteman Bikeway and Nashua River Rail Trail compared the property values of homes near rail trails to surrounding homes in the same towns. The study found that homes that were not located near rail trails sold for 98.1% of the list price and sold in an average of 50.4 days. Comparatively, homes located near rail trails sold for 99.3% of the list price and sold in just 29.3 days, on average. This study shows that proximity to trails confers a significant advantage in terms of property values and speed of sale. This increase in property value, along with the money generated from activities on rivers, encourages economic prosperity for the community.

2.2.3 Biodiversity

The discharge of pollutants into surface water bodies, soil, and the atmosphere has resulted in ecosystem disruption, natural habitat loss, and an extreme reduction in biodiversity. The magnitude of ecosystem disruption has been in question for decades and a recent study conducted by the World Wildlife Fund suggests that the world populations of “mammals, birds, reptiles, amphibians and fish, has declined by 52 percent since 1970” [McLellan (2014)]. This steep decline in wildlife population has brought new attention to the importance of maintaining and protecting biodiversity.
The underlying premise of biodiversity is that different organisms provide different services for each other and for the benefit of their ecosystem. A diversified group of organisms works in unison with climate, available resources, and react appropriately to disturbances in order to positively influence their ecosystem. Forest environments such as the Cook Conservation Area are regarded as extremely important habitats because they are centers of biodiversity and provide important ecological services to the environment and human welfare [Ojea, Nunes, and Loureiro (2010), 329-347]. In a forest environment such as the Cook conservation area, a diversified biological population regulates air, soil, and water quality, controls erosion, pollinates plant life, cycle’s nutrients, and produces offspring to continue this cycle [Corvalan, et. al (2005), 2]. These ecosystem services are vital for the continued development and health of biological life.

Unfortunately, the natural resources that result from a diversified biological presence are “under intense pressure from development and fragmentation, unsustainable use, pollution, and impacts from a changing climate” [United States Department of the Interior (2011), 1]. While forest environments are becoming increasingly fragmented by developments and their resources are being extracted at unsustainable rates, humans are becoming detached from the natural environment. Early Americans were actively engaged in working with nature and reshaping it for their own purposes but, “Americans today have become increasingly disconnected from our great outdoors. We find ourselves cut off from the natural and cultural inheritance that has shaped our lives and history” [United States Department of the Interior (2011), 1]. Today, the vast majority of the population lives in isolation from centers of biodiversity. As a society, we have essentially created “islands of biodiversity conservation with little or no connection to nearby human lives” [Buta, Holland, and Kaplanidou (2014), 1]. The disconnect between human
populations and resource depletion has created a big problem. Not only is biodiversity declining but the vast majority of humans are not connected with centers of biodiversity and therefore feel no compulsion to protect ecosystems. Overall, the importance of biodiversity and the threat of species loss bring about the need for responsible land use, reconnecting humans with the environment, and developing an invested group of environmental stewards committed to protecting environmental welfare.

2.3 Strategies for Maintaining Rivers

Biodiversity protection, pollutant mitigation, and erosion control are some of the most important methods of protecting natural resources. This section will discuss these methods in detail.

2.3.1 Protecting Biodiversity in Recreation Areas

Experts have suggested that one of the best ways to protect biodiversity in parks and conservation areas is to engage and expand the area’s user base. A recent study published in the *Journal of Outdoor Recreation and Tourism* found that increasing user attachment to recreation areas through awareness, programs, and initiatives “is one of the key concepts at the roots of community action that ultimately fosters community development and sustainable resource management” [Buta, Holland, and Kaplanidou (2014), 2]. A common issue facing rural recreation areas is that surrounding communities are unaware of the areas existence and therefore have no attachment or stakes in protecting the land and the species within it.

However, if local residents make use of a recreation area, continued and satisfied interaction with the land creates place attachment between the user and the recreation area that supports resource protection, and development [Buta, Holland, and Kaplanidou (2014), 2]. Place attachment is a term used to describe a user’s psychological attachment to an area created by the
development of rich memories that inspire users to return to an area. A significant factor that influences place attachment is the ability of nature to relieve stress, improve cognition, and provide recovery from mental fatigue [Maller, et al. (2005), 48]. Results of a recent study on the relationship between children’s psychological restorative experiences in nature to pro-environmentalism indicate, “perceived restorativeness, a psychological process for the renewal of depleted capacities, may help to form and develop pro-environmental attitudes and behaviors” [Collado and Corraliza (2015), 50]. The ability of parks and open spaces to improve mental health is significant. When people experience positive psychological and physical benefits from recreation spaces, they will have a significant impetus for protecting that space.

The establishment of an avid user base at a conservation area begins with making people aware of the land’s presence. Methods of increasing awareness include signage and the creation of publicly available materials that welcome visitors. In fact, information services are a significant influencer of satisfaction among park users [Graefe and Burns (2013), 36]. Continuously updated information enhances user experience and provides users with a sense that the land is relevant. Stagnant, unchanging land can easily become boring and obsolete but continuing to update materials creates a sense of relevancy and motivates visitors to return. Supplying trail users with maps, nature guides, updates on trail closures, recent wildlife sightings, safety concerns, and upcoming events are all ways of providing users with updated information services.

The most important factor indicating a recreationist’s satisfaction with a park is the visual appearance and aesthetics of the land [Graefe and Burns (2013), 36]. The natural beauty of a space, the appearance of man-made structures, and park cleanliness influence user satisfaction and help strengthen a user’s attachment to the land. In fact, a 2013 study on the driving forces of
satisfaction in recreation areas found that “feelings about the appearance of the area were the strongest predictor of satisfaction with facilities” [Graefe and Burns, (2013), 45]. Users enjoy clean spaces and often times a clean space will motivate people to keep it clean. Park cleanliness and developing aesthetically pleasing structures are areas of primary concern for park managers looking to develop and increase their user base.

Enhancing user access by establishing accessible and adequate parking accommodations is another key factor that promotes user satisfaction. If users are continuously unable to find parking, they will become frustrated and less likely to return. In summary, establishing an avid user base and satisfying those users through good maintenance, accessibility and information services will in turn benefit the land as users will depend upon and care for the resources within the area.

2.3.2 Riparian Ecosystems

Recreational activities contribute to well-being at the individual and community level. Family bonds are strengthened by leisure activities, kids can grow healthy and social, and individual self-esteem can be enhanced. Positive effects of recreational activities also apply at the community level. Communities with numerous facilities may take pride in the activities offered to its members. Reports have claimed that towns with newly improved recreational activities result in decreased crime rates [National Recreation and Park Association (2014)]. Despite the pleasant advantages brought by recreational activities, all levels of human recreation contribute to the accumulation of anthropogenic contaminants. Ranging from canoeing and swimming to camping and hiking, human activities have the potential to adversely influence riparian ecosystems [Fresque and Plummer (2004), 1].
Aquatic ecosystems are heavily affected by water recreations. Human waste from various activities is left behind in water sources and disrupts aquatic ecosystems ranging from vegetation to animals. Motorized boats can directly contaminate water by releasing oil and other chemical waste; this disrupts the pH balance of water and leads to depletion of oxygen and other nutrients required for aquatic life. Boat propellers can also contribute to the destruction of water vegetation and kill or injure aquatic wildlife. Seemingly harmless activities such as swimming or canoeing may also contribute to human waste buildup and contribute to erosion of topsoil, waste accumulation, and arousal of wild habitats [Fresque and Plummer (2004), 2-4].

Recreational activities that take place outside the waters also impact trails and soil tops. Walking or hiking can lead to trampling of the soil and vegetation around the riverbeds and subsequently leads to degradation of topsoil and grass slopes. With continued exposure to human activities, soil will lose its ability to infiltrate, resulting in topsoil runoff. Erosion around riverbanks is particularly responsible for contamination of rivers with sediment residue settling and accumulating at the bottom of rivers. Camping also leads to trampling of soils and human waste build up; waste left behind from the camping sites will eventually find its way into riverbeds [Fresque and Plummer (2004), 2-3].

If no preventive measures are taken, repeated human-induced waste will continue to deteriorate riparian ecosystems. Thus it is crucial to educate the public about the environmental consequences associated with recreational activities. It is therefore, important to set constraints and place appropriate regulations on various activities in order to preserve riparian ecosystems.

2.3.3 Soils & Erosion

Stream bank erosion is a naturally occurring process where moving water, wind, and ice remove soil particles from a stream bank over time. Erosion is exacerbated by changes in stream
velocity, runoff water, and changes in stream flow depth. When high flows persist for an extended period of time, the effects of erosion can result in several feet of soil removal per year. It follows that erosion control is crucial to the stability and performance of trail bridges.

The installation of a bridge effectively modifies a stream channel by altering channel dimensions and loading the surrounding soil mass. Common stream channel alterations include modifications to stream depth, width, and perching [Singler and Graber (2005), 4]. These modifications can have significant impacts to stream flow and aquatic life.

A perched crossing, where the crossing entrance is at a different elevation than the downstream end can obstruct the bidirectional passage of fish and wildlife and should always be avoided. Perched crossings result from the improper installation of closed bottom channel modifications and the natural erosion of streambeds over time. Shallow and narrow crossings are also dangerous to wildlife because they provide insufficient water depth for the passage of aquatic life and often modify stream flow, which results in scouring of the stream channel and erosion of the stream bank. In summary, stream crossings should be sunk into the streambed, utilize natural substrates, and have adequate dimensions to avoid erosion and structural stability concerns [Singler and Graber (2005), 7].

2.4 Historical Background

The history of the town of Lancaster is closely tied to the health of the Nashua River. When Rufus Dawes wrote in 1830 of the Nashua as a romantic river flushed with salmon, he was alluding to the public’s love and admiration of the river [See epigraph on Page 1]. Since that time the river has experienced significant transformations in quality. The recent cleanup efforts have resulted in the river regaining its former admiration. This effort has caused the Nashua River to transition from a detriment to the community into a precious and treasured resource. The need to
protect these resources has caused the creation of protective agencies that have authority over the construction and events that occur near these rivers.

2.4.1 Cook Conservation Area

The Cook Conservation Area (Cook’s) is a heavily forested mixed-use recreation area that lines a stretch of the Nashua River in Lancaster, Massachusetts. Located approximately a mile and a half north of Route 117 on the west side of Lunenburg Road, Cook’s fishing inlets, diverse plants and animals, and cart path make it an inviting space for a wide range of visitors. With increasing frequency over the past couple of years, Cook’s parking lot fills with cars driven by a loyal group of dog walkers, bird watchers, horseback riders, hikers, and other recreationists seeking exercise and fresh air [Christopher (2013)].

Surprisingly, Cook’s was not always the vibrant recreation area that it is today; in fact, the conservation area has faced a series of challenges dating back to the arrival of English settlers in the 1620s. At that time, a group of Algonquian Indians, the Nashaway tribe, depended on the Nashua River for their survival, and served as its primary stewards. While the Nashaway’s views and opinions have largely been lost through the passage of time, European settler’s views of the land sum up the key ideological differences that pitted the Nashaway’s concern for the health of the land against European interests of colonization and industrialization.

When English settlers arrived in Lancaster, they were astonished by the tribe’s lifestyle and failure to “improve” the land. Francis Higginson observed in 1621, “The Indians are not able to make use of the one fourth part of the land; neither have they any settled places, as towns, to dwell in; nor any ground as they challenge for their own possession, but change their habitation from place to place” [Lepore (1999), 76]. English settlers felt justified in pressing their own land claims in the absence of permanent towns, and the apparent nomadic lifestyle of the native
peoples. As an increasing number of English settlers believed that Indians were not making proper use of their land, English settlers moved quickly and decisively to take advantage of the situation at the expense of the Nashaway and surrounding tribes.

The Nashaway people initially perceived English settlers “as superior beings; [and] feared their far-reaching muskets; hoped for their protection against the predatory Mohawks, and craved the hatchets, knives and other skilled handiwork of the smiths, and the cloths, kettles, fish-hooks and gewgaws of their traders” [Hurd (1889), 12]. Their dependence on English goods led to forced trades and the development of hostilities between the colonists and Indians. These hostilities culminated in King Phillip’s War, which reached colonial Lancaster on February tenth, 1676. In the days after their initial attack, Nipmuck Indians attacked the Lancaster settlers, “sacking, burning, killing, and taking hostages. With the exception of two houses… everything was destroyed” [Darby and McCrosky (1994), 10]. Mary Rowlandson, a prominent minister’s wife, documented her three-month experience among Indian captors in a memoir called *The Narrative of the Captivity and Restoration of Mrs. Mary Rowlandson*. The capture of Mary Rowlandson and the destruction of approximately twelve colonial New England towns provided significant impetus for an effective English response. In August of 1676, an Indian named John Alderman who was allied with the Plymouth Colony militia shot and killed Metacom (King Phillip). As a result, the English settlers were victorious in establishing their claim to the land.

The incorporation of Lancaster in 1653 marks an important historical transition from Lancaster as an indigenous Nashua world to a river valley being settled and developed by Europeans. At the outset, Lancaster’s residents followed in the Nashaway’s footsteps and engaged in an interdependent relationship with the river. Settlers lived in harmony with the Nashaway Tribe whose members were instrumental in teaching skills such as hunting and fishing
Like the Nashaway, the early settlers profited from anadromous fish runs of salmon and shad but they also brought with them a unique skill set that eventually diminished their dependence on the Nashaway. The arrival of a blacksmith named John Prescott in 1647 had lasting impact on the settlement and was ultimately responsible for giving Lancaster its name. Prescott’s followers petitioned the Massachusetts General Court to incorporate their town in May of 1652 and name it Prescott. The court refused this name likely because they looked down on Prescott as a “blacksmith who was no freeman, and had but recently taken the oath of fidelity” [Hurd (1889), 4]. After several suggestions, the court agreed to name the town after Prescott’s birthplace, Lancaster, England. In 1653, Prescott was granted approximately eighty acres of land for the establishment of a corn mill, which began operating in March of 1654 [Norse (1884), 32]. The corn mill was a great advancement for the early settlers because “until that began its tireless turning, the grain for their every loaf of bread had to be carried to Watertown mill, or ground laboriously in a hand quern” [Norse (1884), 31].

Prescott’s ingenuity and talent not only inspired his neighbors to name their township after his birthplace, but it caused a shift in dependence – the English settlers were no longer dependent on the Nashaway. Prescott’s establishments would eventually disrupt the symbiotic relationship that once existed between the Nashaway and English settlers, “never again did they fish the Nashua for Salmon or roam through the pine forests on the river bank tracking down game… the power of the Southern New England Indians was broken forever” [Kirkpatrick (1971), 61]. By 1760, the Nashaway and related tribes gave up on attacking Lancaster and the health of the land was in the hands of the English settlers.

Environmental consequences resulting from the transition of power from the Nashaway and other Indian tribes to the American colonists would become most evident upon the coming
of the Industrial Revolution at the turn of the nineteenth century. The result of industrialization was a retreat indoors, away from long held traditions of agrarian life and towards patterns of consumerism and specialization [Sachs (2014), 4]. While Lancaster held on to its agrarian roots, towns upstream such as Fitchburg, and Leominster became centers for the production of paper, paint, locks, and keys [Eggleston, Hu, and Noons (2013), 42]. For many years, these thriving industries produced great quantities of goods and discharged their waste straight into the Nashua River and its tributaries [Eggleston, Hu, and Noons (2013), 7]. The Nashua River became so polluted that by 1965, the Nashua was among the nation’s ten most polluted rivers.

The Nashua River had become lifeless, unsightly, and foul-smelling due to the limited vision of industrial and civic leadership, and a fatalistic sense of complacency that afflicted most ordinary citizens. The toxic brew of sewage, industrial waste, and heavy metals kept everyone away from the river with the exception of a select group of activists brave enough to demand change. The Nashua River Clean-up Committee formed by Marion Stoddart worked with Bill Flynn, the mayor of Fitchburg, Mass., and other government organizations to end the discharge of pollutants into the Nashua River. The people that Marion Stoddart inspired were also staunch advocates of the Clean Water Act, passed in 1972 to prevent the Nashua and other rivers in the U.S. from becoming more polluted.

The health of the land surrounding the Nashua River has improved tremendously since it flowed red in the 1960s, thanks to a similar group called the Lancaster Friends of the Nashua River. Under the auspices of this group, members of town government and citizens have devoted their time towards opening Cook’s for public access, promoting community awareness of the recreation area, and planning for future improvements.
The ability for citizens of Lancaster to access Cook’s has continued to improve since George H. Cook ceded the land to the town of Lancaster in 1975. After being closed for several years, the LFNR along with the Lancaster Land Trust and other stakeholders lobbied for the reopening of Cook’s in 2012 [Lancaster Friends of the Nashua River (2014)]. Since then, Cook’s has seen a host of improvements and increased use by recreationists of all kinds. In 2013, a WPI project team completed a boundary survey, trail map, and documented the history of land use within Cook’s [Eggleston, Hu, and Noons (2013)]. Since its reopening, the Conservation area gained a regular user base of dog walkers, hikers, and nature enthusiasts. The presence of Geocaches and QR code scavenger hunts also indicates that a specialized group of recreationists make use of the land.

2.4.2 Agencies Involved with Rivers

There are many organizations, associations, and groups that manage and regulate public land through a strict set of codes and standards. Any change to a public area has to comply with the regulations set forth by organizations, public and private. This section will outline the functions and importance of these governing organizations.

In 1969, The Nashua River Clean-up Committee (NRCC), founded by Marion Stoddart in the 1960s, evolved into the Nashua River Watershed Association (NRWA). This organization was formed to mitigate environmental stressors and eliminate pollution of the Nashua River. There was a huge need for something to be done to the river because pollution levels were high enough to render the water useless for any recreation purpose. For those who lived near or around the river, it was a serious health risk. This organization is a non-profit group that conducts all of its work through donations. With donations from the public, it is possible to accomplish their goals: to protect the water, land, and community assets of the Nashua River.
watershed area. This association has stretched over municipal borders to over 32 communities throughout the watershed area. Environmental education is an integral part of the association: they run various programs that bring schoolchildren to the river and teach about the habitats, animals, plants, and how these aspects interact along the Nashua River [Nashua River Watershed Association (2012)].

Founded in the 1960s, Lancaster Friends of the Nashua River (LFNR) works to ensure that the segments of the Nashua that flow through Lancaster are maintained in an acceptable manner. This group works in conjunction with the NRWA to maintain the river area, while also making it more accessible and attractive for public use. The Lancaster Nashua River Festival, an event organized by the LFNR, brings the Lancaster community together in a fun and unique way with the common interest being the Nashua River. River tours via canoe and kayak, fishing lessons, and general river education highlight the festival [Lancaster Friends of the Nashua River (2014)].

The Massachusetts Division of Fisheries and Wildlife (DFW) take responsibility for the restoring, managing, and protecting fish and wildlife resources for the benefit of the public. Founded in 1866 in response to the loss of Atlantic salmon due to dams and pollution, this group provides information to the public on almost all river/water bodies in Massachusetts [Executive Office of Energy and Environmental Affairs (2014)]. The Central Nashua River Valley is shared between Bolton, Harvard, Lancaster, and Leominster. The DFW works in conjunction with many smaller organizations to ensure the cleanliness, fish population, and other wildlife, across the 12,900 acres of the Nashua River Valley are taken care of.

Enforced by the United States Department of Justice, the Americans with Disabilities Act (ADA), was signed on July 26, 1990 [United States Department of Justice (2014)]. The goal of
this act was to establish equality among those with and without disabilities. This act gives the Department of Justice the power to establish criteria for construction of public use areas. All people must be able to access the area, no matter their disability. For example, an extension of the act describes the width of walkways to be used in public access routes, slopes for ramps must conform to maximum grades, and adequate parking must be supplied and labeled for those with handicapped vehicle tags. In regards to Cook’s, the proposed bridge designs must pass a multitude of dimensional tests in order for construction to be approved.

The United States Environmental Protection Agency (EPA) was founded on December 2, 1970 [United States Environmental Protection Agency (2014)]. The purpose of the United States Environmental Protection Agency is to protect the environment from many risks. This federal organization develops and enforces regulations on environmental law, gives grants to various environmentally focused institutions, studies environmental issues throughout the nation, and shares the discoveries publicly. They sponsor partnerships with many businesses and non-profits as well as state and local governments, which open up teaching opportunities for the public about environmental issues. The EPA is the primary enforcer of regulations that hold across the United States. Environmental Police can cite persons for breaking any regulation. Two of the many violations in existence that are subject to fines are modifying a wetland without a permit and vandalism of any kind.

Founded in 1896, the Massachusetts Audubon Society was created by two women, Harriet Lawrence Hemenway and Minna B. Hall. These women worked to stop the cruel nature of killing animals to decorate the large hats women wore in the nineteenth century [Mass Audubon (2014)]. This society developed into one of the major conservation societies in Massachusetts. This society conducts species inventory, purchases sanctuary land, and works to
maintain the parcels of land they purchase. The Mass Audubon conducts sanctuary-based monitoring of species ranging from birds to reptiles and amphibians. Many of the Mass Audubon land holdings have been acquired thanks to generous donations from the public. Once this society acquires a parcel of land, the land is permanently transformed into a wildlife sanctuary. This allows the public to view the area while simultaneously protecting it from future developments and destruction. When a parcel of land is designated for preservation, the Mass Audubon Society engages in maintenance of the environment to enhance the rare or endangered habitats present. If a particular habitat is damaged or compromised, restorative processes are employed in an attempt to restore the original grandeur. In regards to any holdings in Lancaster, the closest parcel of land owned and managed by the Massachusetts Audubon is Lincoln Woods in Leominster.

The US Army Corps of Engineers was founded on March 16, 1802. This organization is a division of the military in which engineers establish requirements for any type of United States infrastructure. The Corps is responsible for thousands of dams and projects across the United States. They have become the engineering superpower in the States and have established a set of engineering standards that are universally followed and referenced [US Army Corps of Engineers (2014)]. In Lancaster, the Corps has many bridge designs and methods for creating trail systems. This information is useful because it gives a starting point to any engineering challenge.

2.4.3 History of Bridges

Before European settlement, Indians situated along the banks of the Nashua revered the river for its nourishment. Indians made use of the Nashua River as a source of drinking water and fish; they found few reasons to build bridges across rivers. European settlers, on the other hand,
sought to use rivers for agriculture, domestication of animals, milling operations, and to connect with nearby settlements. In order to complete these activities, settlers determined that bridge construction was necessary for their long-term success [Steinberg (1991), 25-26].

Before the construction of bridges, settlers would swim across waters carrying their wives and children. Other methods of crossing rivers for the early settlers included using canoes or small flat-bottom boats [Steinberg (1991), 27]. Construction of footbridges eliminated various inconveniences such as swimming or canoeing across water sources as well as shortening travel time.

Pedestrian bridges, otherwise known as footbridges, were the first bridges constructed in early America and consisted of fallen trees or pieces of wood bound together by local carpenters. Wood was predominantly used, due to its abundance and inexpensiveness for New England settlers. Bridges allowed transportation across rivers more than before, and wherever bridges were built, mills were established, wherever mills were established, settlements increased in size and self-sufficiency.

In the early settlements, mills provided settlers with clothing, food, and shelter [Steinberg (1991), 28]. With settlers’ increase in skill and design sophistication, bridges were constructed to support heavy wagons and facilitated the transport of essential goods.

Streams and creeks were the first to be bridged due to their relative small size. With a lack of advanced materials and technology, building bridges across vast waterways posed numerous difficulties to settlers. The Nashua River, for instance, lacked a solid and firm basis to support bridge footings and made bridge construction very difficult. Other challenging situations involved with bridge erection include ice and snow that form during New England’s harsh winters and deteriorate bridge structures [Marvin (1879), 79-90].
Due to the tendency of wooden bridges to decay, covered roof bridges, such as the one shown in Figure 3, were introduced to shelter bridge decking and rails from the effects of the environment. Century’s later; covered bridges remain a significant landmark throughout New England.

![Covered bridge in New Hampshire](image)

**Figure 3: Covered bridge in New Hampshire [Sparks (2008)]**

A variety of materials were used to build early pedestrian bridges. Stone bridges, compared to wooden ones, were far sturdier and served an aesthetic purpose as well. Although stone bridges cost double or triple the amount of wooden bridges, mill owners preferred stone bridges for their capacity to support heavy wagons loaded with goods [Baus (2008), 10].

Before long, trained engineers replaced small town carpenters in the construction of bridges and expanded societies ability to span larger gaps. Bridge construction became more durable but also more complex and new materials including steel and reinforced concrete facilitated the construction of sturdier bridges to span longer gaps. Nonetheless, primitive footbridges still maintain their usefulness to daily pedestrians.

Footbridges transformed the American landscape and produced an enduring legacy of the early settlers. Architectural historian, Ursula Baus defines a footbridge as something which, “does not remain a bridge, but matures into a jogging track, a boulevard, a promenade, a place
for rendezvous and, finally, a landmark,” [Baus (2008), 12]. In the same way, bridges built in
seventeenth and eighteenth century New England served as a mode of transportation and as
significant landmarks, which reveal the challenges of life to early settlers.

2.5 Environment, Philosophy, and Design

Few individuals have the ability to shape the way future generations will solve problems.
As we look backward through the past centuries, a few key conservationists and architects stand
out for their thoughts about the fruitful marriage of structure with nature.

2.5.1 Aldo Leopold

Aldo Leopold (1887-1948) was a naturalist on “the cutting edge of conservation activity
and environmental thought. His actions and ideas defined the basic issues that challenged
conservation in his time – and continue to do so in ours” [Meine (2010), xii]. Leopold’s most
notable work, *A Sand County Almanac*, is a collection of essays revealing his opinions on nature
and conservation. One of Leopold’s main concerns was the development of a land ethic. For
Leopold, “an ethic, ecologically, is a limitation on freedom of action in the struggle for
existence” [Leopold (1949), 168]. By extension, a land ethic,

- reflects the existence of an ecological conscience, and this in turn reflects a conviction
  of individual responsibility for the health of the land. Health is the capacity of the land
  for self-renewal. Conservation is our effort to understand and preserve this capacity.
  [Leopold (1949), 186]

Leopold had a unique ability to explain very complicated concepts in a persuasive and
captivating way. He published over 300 pieces on the environment and was the most influential
conservationist of his time. His work continues to shape our appreciation for the environment
and has had significant impact on the way we thought about conservation.
2.5.2  Frank Lloyd Wright

No stream rises higher than its source. Whatever man might build could never express or reflect more than he was. It was not more than what he felt. He could record neither more nor less than he had learned of life when the buildings were built. His inmost thought lives in them. His philosophy, true or false, is there

-Frank Lloyd Wright 1953

Frank Lloyd Wright (1867-1959) was the pioneer of organic architecture, which is reflected, in one of his most prolific works, called Fallingwater, shown in Figure 4. Located in rural southern Pennsylvania, Fallingwater is imbedded into a waterfall and encapsulates Wright’s design principle of combining human ingenuity with the aesthetics of nature. As an architect, Wright created truly original works and was highly motivated by what he perceived to be America’s acceptance of mediocrity. In his autobiography, Wright described American architecture by stating, “in general, and especially officially, our architecture is at long last completely significant of insignificance only. We do not longer have architecture. At least no buildings with integrity” [Wright (1932), 337]. His staunch opposition to imitations combined with his belief that, “only a development according to nature, an intelligently aimed at purpose, will materialize this ideal” [Wright (1953), 125] resulted in structures of the most impressive form, function, and aesthetic appeal. Needless to say, Wright’s passion for organic architecture has significantly influenced our design choices.
2.5.3 Frederick Law Olmsted

Frederick Law Olmsted (1822-1903) was the father of landscape architecture and a firm believer in the preservation and advancement of land through organic design. Olmsted is most known as the co-designer of Central Park in New York City. His vision defined the look and feel of hundreds of important spaces across the United States and abroad. As a humanist, Olmsted believed that beautiful environments could profoundly affect society, “It is a scientific fact that the occasional contemplation of natural scenes of an impressive character, particularly if this contemplation occurs in connection with relief from ordinary cares, change of air and change of habits, is favorable to the health and vigor of men” [Olmsted (1865), 17]. Olmsted worked hard to respect and preserve nature “decades before the environmental movement became a force in American politics” [Public Broadcasting Service (2014)]. He is famous for achieving “the genius of a place,” a term he used to describe the integration of structures to fit the unique characteristics of a site [Beveridge (2000), 36]. His ultimate goal was to heighten human experience of the environment by hiding his improvements in order for function to give way to form. His work in sustainable design and environmental conservation continue to define the way architects shape landscapes in the present day.
3.0  Methodology

Given our project goal (improving visitor access to the Cook Conservation Area trail network along the Nashua River in Lancaster, Massachusetts), we established the list of objectives provided below. This chapter describes our group’s approach and the methods required to fulfill each of these objectives:

1. Gain an understanding of common use patterns, activities, and desired improvements from trail visitors.
2. Explore the requirements for designing accessible, historically appropriate, and environmentally sustainable structures in conservation areas.
3. Design structures that meet the functional and aesthetic needs of stakeholders while utilizing the best practices of engineering and sustainable land use.
4. Assess the feasibility of constructing the desired improvements given land and budget constraints.
5. Provide recommendations and detailed plans to the LFNR for the construction of the trail bridges.

3.1  Assess Visitor Priorities

In order to better understand the needs and preferences of the community members who frequent Cook’s, we designed a simple survey. This brief survey (occupying just 1/3 of a standard sheet of paper) was intended to record visitor use patterns and preferences, and to provide suggestions about potential improvements to be considered.

In creating a survey form, we devised five practical questions, which allowed the respondents to provide feedback on their experience at Cook’s. Two questions on the survey were preference questions asking the site visitors to rate from 1 to 5, with one being the least, the efficiency of creating a handicap accessible picnic area. In the same manner, a question was asked regarding how much visitors would benefit from improvements made to the trail bridges.
The remaining questions asked trail users to indicate the types of activities done at the site, the frequency with which they visit, and their overall thoughts on the maintenance of the site. In addition to the questions above, we also included an open-response section at the bottom of the survey where responders could suggest improvements or make comments. The complete survey is provided in Appendix A1.

Once the survey questions were created, we considered potential ways of administering our survey. In order to maximize convenience for the visitors and to enhance the likelihood of responses, we constructed and installed a survey box at the trailhead. The design of the box accounted for rainfall by having a cover to protect the paper surveys within. The team visited Cook’s and affixed the survey box to the trailhead kiosk in order to maximize contact with trail users.

In order to reach users that would prefer an electronic version of the survey, we created an online surrogate and utilized a QR code that led survey responders directly to a website with our electronic survey.

In the interest of exploring the social implications of our project and aligning our engineering solutions with the needs of the community at large, we analyzed survey responses using a holistic approach to statistical analysis and balanced the importance of both the qualitative and the quantitative input collected.

3.2 Determine Structural Design Criteria

In the initial stages of our project, the group was presented with two project options from our sponsor, LFNR, which were aimed at improving the community’s access to the Nashua River. The first option was to create a handicap accessible picnic area near the trailhead of Cook’s. The second option was to replace two old footbridges located within the trail system. As
mentioned above, our group conducted a survey analysis to observe user preferences regarding the two options. The data was analyzed, and replacing pedestrian bridges turned out to be the major trail improvement focus for our group’s work. We not only aimed at replacing the bridges to improve public access to Cook’s, but also aimed at designing a bridge structure that would be handicap accessible, structurally sound, aesthetically pleasing, and cost-friendly.

Cook’s is situated within the Central Nashua River Valley, which according to the Massachusetts’ executive office of energy and environmental affairs, is considered to be an Area of Critical Environmental Concern (ACEC). ACECs are defined as “places in Massachusetts that receive special recognition because of the quality, uniqueness and significance of their natural and cultural resources,”[Executive Office of Energy and Environmental Affairs, (2015)]. In order to respect this designation, bridge structures with minimal environmental impacts were investigated. In pursuance of making the bridges handicap accessible, we focused on designing bridge rails in accordance with the ADA. One of the main considerations in designing the bridges was aesthetics. We worked to create a design, which does not distract viewers from the scenery of Cook’s. Our group aimed at coming up with an aesthetically pleasing design by weighing out the pros and cons of various bridge structures.

3.2.1 Handicap Accessibility

One important design requirement for the construction of trail bridges is handicapped accessibility. This restriction directly affects the design and dimensional characteristics of the bridges.

The Department of Justice regulates minimum dimensions or passageways for travel through the Americans with Disabilities Act (ADA). In order for a new public walkway to be constructed, it has to be ADA compliant. We referenced 2010 ADA Standards for Accessible
Design 28 CFR 35.151 for all of our dimensional criteria. We were able to gather logistical requirements on parking, ramps, landings, walking surfaces, and railings as they related to our design from the 2010 ADA Standard for Accessible Design 28 CFR 35.151.

Sections of the ADA standard most pertinent to our project goals include specifications for walking slopes, ramps, railings, and landings. For the design of walking slopes: running slopes should be no steeper than 1:20 and cross slopes no steeper than 1:48. For every change in level greater than 1.5 inches, a ramp is necessary. The running slope or the ramp should be designed for a slope no greater than 1:12. The maximum rise for the ramp is limited to less than 30 inches. Each ramp requires a landing at the top and bottom of the incline. Landings must be designed to be at least as wide as the approaching ramp with a clear length of at least 60 inches.

In designing railings, we considered various requirements that would enhance the safety of the bridges. At the base of the railings, a maximum of four inches is required such that a wheelchair in crossing would not fall off the edge. The top surface of the handrails should be positioned between 34 and 38 inches from the base of the decking to achieve optimal height for occupants. Handrails must be designed to be fixed and free of sharp burrs or imperfections.

3.2.2 Aesthetic Choices

In pursuance of our goal to create aesthetically appealing bridges, we analyzed common pedestrian bridge designs both in person and using online resources. Our team made a site visit to Buffumville Park in Charlton, MA, and took photographs of four pedestrian bridges along the trail network. We assembled a document containing pictures of pedestrian bridges from our site visit and from online research and highlighted the benefits and drawbacks of each design. We focused primarily on choice of materials, orientation of structural members, compatibility with
the surrounding landscape, and ease of construction. The optimum design choices of each bridge were accentuated and incorporated into our final bridge design.

3.3 Assess Local Conditions for Bridge Structural Design

Once the community’s preference for new bridges was confirmed, our group needed to outline a process for determining the feasibility of constructing new bridges in place of the currently inadequate stream-crossings at two locations along the trail. The first of these bridge sites is located at the crossing of the McGovern Brook, approximately 0.5 miles along the Farnsworth Trail (Farnsworth - 0.5 Mi.), while the second bridge site is located at the crossing of an unnamed intermittent stream approximately 1.5 miles along the Farnsworth trail (Farnsworth - 1.5 Mi.). In order to determine the feasibility of constructing a bridge at each of these sites, our group examined each of the two sites.

3.3.1 Determine Soil Types

We began to prepare for and determine the feasibility of the design process by investigating the soil types and conditions at each of the proposed bridge sites. In order to get started our group met with WPI professor Rajib Mallick to determine the steps necessary for ascertaining the soil types and the resulting soil bearing capacity at each bridge site. Professor Mallick recommended two tests for our group to perform: a Sieve Analysis test and an Atterberg Limits Test. These two tests, along with published classification standards from the American Society for Testing and Materials (ASTM), would provide us with a definitive means of identifying each soil type [Interview with Professor Mallick (2014)]. The team conducted a field visit to collect a soil sample from each bridge site; the field report for this visit can be seen in Appendix H3. We collected soil in close proximity to the foundation locations of the replacement bridges without compromising the integrity of the current bridge foundations or the
safety of trail users. Once these samples were collected, our group separated, oven dried, and massed a small portion of each sample to prepare it for testing.

A sieve analysis is the first test in determining the soil type for a given sample. Our group consulted the *ASTM D6913-04 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis* to determine the procedure for the sieve analysis [American Society for Testing and Materials (2009)]. In order to conduct a sieve analysis of a soil sample the order of the sieves needs to be determined. Each sieve has a standardized opening size. The sieves are ordered in descending order with the largest at the top and the smallest at the bottom. Underneath the smallest sieve size is a pan which is used to collect the sample that passes the smallest opening. According to ASTM standard D6913-04 the sieve set used must include the No. 4 sieve and the No. 200 sieve [American Society for Testing and Materials (2009), 7]. The reason for the inclusion of these sieves is to serve as boundaries between particular soil types. All particles that are retained by the No. 4 sieve are considered gravel, while all particles that pass the No. 200 sieve are considered silt. Once a sieve set is chosen, each individual sieve weight must be noted and arranged in descending order. The soil sample is poured into the top sieve, which is then loaded into a mechanical shaker and shaken for 10 minutes, as shown in Figure 5. This process insures that each particle passes the smallest sieve size possible. After the

![Figure 5: Sieve stack loaded into the mechanical shaker for the sieve analysis](image)

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sieves are shaken, each one must be massed with the particles it retained. The mass of the empty sieve must be subtracted from the mass of sieve with retained particles to determine the percentage of the sample retained by each individual sieve. This data along with the data collected from the Atterberg Limits test can then be used to classify the soil.

The Atterberg Limit test consists of two tests. The first test is the liquid limit test; this consists of using a cup apparatus and grooving tool, seen in Figure 6, to determine the liquid limit of the soil. Water is added to the sample and a small amount of soil is spread on the cup. The grooving tool is used to create a predetermined separation in the soil, shown in Figure 7. The cup apparatus drops from a measured height and is allowed to contact the base of the soil.
apparatus. The cup is dropped until the groove closes and the number of “blows” are recorded. A small piece of the sample is removed from the cup and placed in a pre-weighed container. These pre-weighed containers are then placed in the oven until the sample is completely dry. The weight difference between the dry and wet samples must be recorded and the moisture content calculated. This process is repeated until four samples of varying moisture content produce results with varying amounts of blows.

To execute the liquid limit test, a grooving tool is required. Due to the lack of a grooving tool in our lab, our group was forced to make one. This process was possible by creating a drawing of the grooving tool in the program AutoCAD using the specifications listed in ASTM D4318–10 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils [American Society for Testing and Materials (2010), 5]. Our group took this drawing to the Versalaser VLS-4.60 laser cutter owned by the WPI Department of Mechanical Engineering and cut a grooving tool out of a ⅜” thick, piece of acrylic. This process is shown in Figure 8.

Figure 8: Versalaser VLS-4.60 Laser Cutter cutting the grooving tool out of a 3/8” thick piece of acrylic
The second half of the Atterberg Limit test determines the plastic limit of the soil. In this test, a small sample is spread on a plate and worked into a strand until it is approximately three millimeters in diameter. If the strand begins to crumble at three millimeters, then the sample is placed in a pre-weighed container. The sample is allowed to dry and the moisture content is calculated. If the sample does not crumble at three millimeters, the moisture content is adjusted and the process repeated.

In order to classify our soil types the *ASTM D2487–11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)* was used [American Society for Testing and Materials (2011)]. The figure shown in Figure 9 is used to classify the soil. The following equations are used:

\[ C_U = \frac{D_{60}}{D_{10}} \]

\[ C_c = \frac{D_{30}^2}{(D_{10} \times D_{60})} \]

Where \( D_{60} \) is the sieve size associated with 60% of the sample passing, \( D_{30} \) is the size associated with 30% of the sample passing, and \( D_{10} \) is the sieve associated with 10% of the sample passing. Once the sample type is determined, the bearing capacity associated with said soil type can be found from published standards and used to determine the required foundation area.
3.3.2 Identify Bridge Locations Precisely

As means of ensuring the ability of the bridge sites to accommodate the proposed bridge structures, Geographic Information Systems (GIS) is necessary. In regards to our bridge sites, data import from the Massachusetts office of Geographic Information (MassGIS) into a GIS program called ArcMap is required. The subsequent datalayers needed then can be imported into ArcMap from MassGIS: Protected and Recreational Openspace, Major Watersheds, Mass DEP Hydrography, MassDEP Wetlands, and NRCS SSURGO-Certified Soils. Farnsworth - 0.5 Mi. can be easily located using ArcMap due to the uniquely identifiable geography of the land. Next step is to join the soils datalayer with a table downloaded from MassGIS that gives soil names. This technique proved to be especially useful as GIS indicated that the soils at both bridge sites were exactly what we classified our soil samples through laboratory testings. We also utilized GIS to create a map of Farnsworth - 0.5 Mi. The map, shown in Appendix G1, displays slope
classes with a color pattern that highlights areas of steep slope and labels soil types and water bodies.

3.3.3 Document Localized Topography at Each Site

A topographical analysis of Farnsworth - 0.5 Mi. was completed using a survey level and a 40 ft. leveling rod. These tools are used to measure elevation points and distances from a benchmark, specifically on the eastern side of McGovern Brook. Elevation measurements at each 3 foot interval provide an adequate spacing for the 30 ft. by 20 ft. grid. At each apparent change in elevation, an additional measurement of elevation is needed to ensure slopes spanning less than three feet are accurately recorded. Water depth is relatively constant, so a singular depth represents the entire stream.

After taking survey points at Farnsworth – 0.5 Mi., 2 dimensional and 3 dimensional representations of the area were constructed. With the data acquired from the site measurements, the surface plot function of Microsoft Excel provided three and two-dimensional maps. In the three-dimensional version, each of the soil type layers was labeled to approximately match the different depth categories.

3.3.4 Investigative Erosion Prevention and Mitigation Methods

Our team researched cost efficient yet effective methods as preventive measures for protecting against soil erosion at the proposed bridge sites. We relied primarily on technical literature to recommend erosion control mechanisms based on site-specific conditions. We also met with Professor Albano in the Civil Engineering department and he provided us with several suggestions for controlling for erosion. Our team examined best practices for constructing erosion prevention systems to improve the safety of volunteers. We measured the distance from the top of the stream bank to the water level at low-flow because depths greater than four feet are
unsafe for volunteer workers and are best handled by experienced professionals with protective safety equipment. We also investigated the effects of stream flow velocity on worker safety.

3.4 Analysis and Feasibility of Design

Once our group gathered information about each bridge site, the feasibility and design of the bridges could be undertaken. The design of each bridge required several considerations in terms of cost, visual appeal, and safety. The cost and logistics for construction of each bridge could then be examined to create a cost analysis and ensure feasibility of construction.

3.4.1 Structural Analysis

After deciding on a bridge design that was both practical and visually appealing, the required sizes for the decking and underlying girders needed to be calculated. In order to accomplish this task our group used the Load and Resistance Factor Design (LRFD) approach. The LRFD approach assigns load factors to anticipated loads in order to account for the relative uncertainty of load magnitude and location.

Determining service loads involves researching the intended uses of the bridges and the loads associated with those uses. The LRFD approach also uses load combination equations to account for hypothetical overload scenarios. Each applicable load combination equation must be calculated to ensure structural integrity. The largest value of the load combination equations is considered the critical loading case and serves as the governing design load. The critical loading case should then be used to determine the size for each structural member.

In order to expedite the sizing process, our group chose appropriate sizes for both the decking and the girders. In order to find the internal forces in each member, these sizes and the critical loading case were entered into SAP2000, a finite element analysis program. Using the inputted data, this program provides the maximum internal forces of moment and shear that each
member experiences [Interview with Professor Albano (2014)]. Our group used the *American Wood Council, National Design Specification for Wood Construction* to determine the maximum moment and shear values that each member size could sustain [American Wood Council (2012)]. This was accomplished by locating the base value in the published tables and multiplying this value by adjustment factors that are specific to our bridge design and site conditions. Allowable values were then compared to the internal forces experienced and the member size for both the decking and girders were chosen. Once the sizes of all the materials were selected, the bridge design could be completed and dimensions could be finalized.

### 3.4.2 Cost Estimation

We estimated the cost of materials, labor, material transportation, and maintenance of the bridges at the two designated sites. Material prices were obtained from several retailers including Home Depot, Lowes, Discount Contractor Supply and Fastenal. In order to calculate the costs that went into the bridge designs, a cost reference sheet was created. This sheet lists materials needed for the structural elements, decking, sonotubes, and concrete. The completed design of the bridge model required 3/4" Galvanized Lag Bolts, 4" x 16" P.T. Lumber, 2" x 4" P.T Lumber, 3/4" Galvanized Timber Bolts, 125' Architectural Steel Cable, 2" x 6" P.T Lumber for decking, 18" diameter sonotubes and 1000 galvanized screws. On top of the material expenses, our team estimated and added costs that go into transporting the bridge materials to the two sites, man labor, and maintenance costs. It should be noted that these values are rough estimates and are subject to change once construction is initiated.
3.5 Model Development and Communications with Appropriate Stakeholder Groups in the Community

In order to provide the LFNR with detailed plans to construct our bridge designs, we created a three-dimensional model and detailed construction drawings using computer aided design (CAD) programs. Three-dimensional modeling serves a dual function in that it helps designers visualize how each piece of the structure fits together during the design process and it has the potential to serve as a visual aid to volunteer workers during the construction process.

The first model created was a three-dimensional model of our bridge design using SolidWorks. Each component of the bridge from connections to structural members was modeled individually and then put together as an assembly. Making an assembly in SolidWorks is similar to constructing a virtual bridge in that the location and orientation of each component must be considered.

Once our team created the three-dimensional SolidWorks model, we utilized AutoCAD to create annotated construction drawings. The bridge drawings include plan and section views of the structure and provide detailed instructions on member sizes and orientations. They also specify materials to be used including type of wood, fasteners, and concrete.

3.5.1 Permitting Process

In designing a bridge to improve community access to Cook’s, our project group wanted to be mindful of all the agencies that are involved with Cook’s. The first step in the permitting process was initiated by consulting Tom Christopher, a representative of our project sponsor and member of the Lancaster Conservation Commission. In order to obtain formal permission from the Conservation Commission, we filled out WPA 3 and notice of intent forms. The purpose of the WPA 3 and Notice of Intent forms is to protect the wetlands in Massachusetts from removal,
dredging, filling, and related alterations without prior notification or alert [Executive office of Energy and Environmental Affairs (2015)]. The forms required us to explicitly detail the amount of wetlands, our intent for construction and the degree of possible disturbances that may arise from our project.

The Central Nashua River Valley, designated as one of thirty Massachusetts ACECs, embodies Cook’s. In order to comply with regulations and restrictions protecting this area, an Environmental Notification Form was required. In the process of seeking approval for our project, the Nashua River Watershed Association was also notified of the group’s intentions.

3.5.2 Notice of Intent Hearing

As a learning exercise, our group participated in a notice of intent hearing before the Lancaster Conservation Commission. This experience intended to prepare us for real world engineering practice. We also used this hearing to understand the additional steps needed to obtain permission for constructing the proposed bridges in Cook’s. In addition, members of the community with knowledge of designing structures in sensitive environmental areas provided additional feedback for our benefit.
4.0 Results

This chapter of the report contains findings and results derived from our survey, interviews, feasibility analysis, structural analysis, modeling and cost estimation along with recommendations for our project sponsor.

4.1 Survey Findings

22 trail users responded to our survey between September and December, 2014. These responses provided useful data on current recreational usage patterns in Cook’s, some clear indications of user preferences regarding some possible proposed improvements to the trail system, and yielded valuable suggestions in addition to the possibilities that our group had anticipated.

Survey responses were processed on a rolling basis as we received them and we continued to refer to data derived from the survey throughout the project. The responses collected from 22 visitors to the site were analytically compared using the unpaired T-test. From the results, we determined that the mean value of the preference of the picnic area was 2.4 (out of 5), and the mean value of the preference of the trail bridges was 3.6 (out of 5), as shown in Figure 10. The difference in the mean values of the two categories was shown to be statistically significant and we were able to conclude that trail users had a greater preference for improved trail bridges than constructing a handicap accessible picnic area.
In addition to their quantitative indications of user preferences, the survey results also documented the major activities performed at the site and the frequency with which users visit the trail network. Regarding the question which asked “how often do you visit the Cook Conservation Area?” we received a wide range of responses from visitors who visited the site for the first time ever to visitors who visited once a year, once a month, once a week, and more than once a week. From these categories the largest group of respondents were frequent visitors who use the Cook’s trails at least once a month, as shown in Appendix A2.

The “typical activities” question revealed that Cook’s supports a wide repertoire of community recreational pursuits. Users reported that they engage in walking, hiking, geocaching, dog-walking, water recreation, spiritual renewal, and nature study. While the highest number of respondents utilized the site for dog-walking and hiking, there were examples of individuals who treasure Cook’s for its peacefulness, aesthetic scenery, and the opportunity it provides for meditation and nature study. A better sense of the site’s current array of multi-uses can be seen in Appendix A2.

Results gathered from the survey analysis directly addressed the societal dimension of our project, and we used the valuable community feedback that the survey provided in order to refine our project goals. During the survey design process we worked hard to develop specific
and targeted questions aimed at answering what we perceived to be the most important questions. Although the numerical ratings questions served important anticipated purposes, answers to the open-ended question, surprisingly, yielded the most valuable information. Added to the survey almost as an afterthought, the open-ended question enabled us to discover additional specific areas of concern that we had not anticipated when designing the survey, such as the need for parking lot improvements. The volume of comments we received brought clarity to our project goal and made our work of improving public access very relevant as we knew people were interested in improving Cook’s. As a result, comments of the respondents were used as a first-hand source in planning improvements to Cook’s and forming future recommendations.

4.2 Bridge Design and Feasibility

We considered whether constructing new bridges would be feasible given the physical constraints of the conservation area based on several criteria including soil stability, dimensional accommodation to provide for ADA compliant structures, slopes and topography. This process was completed after interviewing professors at WPI that have experience with soils and structures. We also obtained field samples, measurements, and performed laboratory testing to determine feasibility.

4.2.1 Aesthetic Choices

Our investigation into aesthetic considerations yielded several of the design alternatives that were incorporated into our final design. For example, although we seriously considered Trex decking as a material for the bridges, since it is visually attractive, we recommended wood as our primary choice of material because wooden bridges blend well into this natural environment and do not detract from the woodland setting. Our group also chose to adopt architectural steel cable for hand rails as we really appreciated the modern look that cables provide.
4.2.2 Soils Testing

A few errors needed to be addressed during the execution of the sieve analysis. During our group’s first test, the bottom pan that we had selected was misshapen. Since the bottom pan was no longer circular it did not fit properly in the mechanical shaker. We did not notice this problem until the shaker was started. Once the shaker started the pan slid off the shaker bottom causing the stack of sieves to detach slightly. A small portion of the sample escaped through this opening, which required another sample to be needed. The next test was invalid due to the sieves being placed in the wrong order. Once the sieves were ordered correctly and a new pan selected, a sieve analysis was properly conducted for each soil sample. All data and charts for the soils testing can be seen in Appendix B.

For Farnsworth – 0.5 Mi., our group used the data collected from the soils tests, the gradation plot for Farnsworth – 0.5 Mi., and the chart shown in Figure 9 in the methodology, to determine the soil type. From the sieve test we found that our sample was 17.13% fine grains because 17.13% of the sample passed the No. 200 sieve. The data from the Atterberg Limit Tests did not follow the typical values associated with a plastic soil. The calculated plastic limit was 27% while the liquid limit was 26%. Since the plastic limit was higher than the liquid limit we were able to conclude the fine grains of our soil were non-plastic. Since the fine grains are nonplastic we could identify them as inorganic silts or ML [American Society for Testing and Materials (2011)]. Finally, we checked our sieve data again to determine that our soil had less than 15% gravel because there was no sample retained by the No. 4 sieve. We then knew the soil type to be silty sand.

The classification of the soil at Farnsworth – 1.5 Mi. (at approximately 1.5 miles along the Farnsworth Trail) involved a similar process. However, the second sample had 9.31% fine
grains. Therefore, we needed to calculate the $C_U$ and $C_C$ values from the sieve test data. From the gradation plot for the Unnamed Intermittent Brook bridge site, we found $D_{60}$ to be 0.2, $D_{30}$ to be 0.12, and $D_{10}$ to be 0.075. Using these values, along with Equations 1 and 2 in the Methodology, $C_U$ was found to be 2.67 and $C_C$ found to equal .96. From the Atterberg Limit Tests, we found the fine grains to again be non-plastic and classified them as inorganic silt, ML. Since the soil was less than 15% gravel, it could be classified as poorly graded sand with silt.

If either soil type was found to be peat or clay there would likely have needed to be a large excavation and subsequent replacement of the soil. These two soil types, however, do not need to be replaced. Our group found that both soil types have the same bearing capacity of 1500 pounds per square foot [Hatch (2007), 6]. In order to design an appropriate and easy to construct foundation, our group looked into the use of Sonotubes [Albano (2014)]. Sonotubes are a brand name for hollow, cardboard tubes which can be embedded in the soil, filled with concrete, and attached to the bridge to form a foundation. Our group began by examining Sonotubes with an 18 inch diameter, which would be embedded four feet into the soil and connected to the bridge. Using the bearing capacity found for both soil types, the weight of the bridge, the loads from the bridge that would transfer to the foundation, and the weight of the foundation our group checked to see if the soil would be able to support these Sonotubes without settling and damaging the bridge’s structure. The team found that an 18” diameter Sonotube did not have sufficient area for the loading experienced. Any Sonotube size larger than this 18” diameter would be irrational, therefore, our group turned to a different solution.

To increase stability, a separate footing could be added to the base of the Sonotube to form a larger area of contact with the soil. For this footing our group looked to Square Foot Concrete Footing Forms. This company manufactures plastic footing forms which are attached to
the base of the Sonotube. The form can be left in the soil with the sonotube, once the concrete is poured. Using the bearing capacity of the soil our group found that a model SF 28 footing was needed to provide sufficient area. Since this footing size only works with certain size Sonotubes, we recommend that a 12” diameter Sonotube be used if this “Sonotube plus footing” configuration is implemented. The calculations for the footing can be seen in Appendix C1.

4.2.3 Bridge Width and Approaches

After assembling all of the minimum dimensional requirements set by the ADA, our group had assembled a list of dimensions. We established that the walking surface should be at least 48 inches wide and have a slope ratio no greater than 1:20. The cross slope was limited to a slope ratio of 1:48. It was determined that our cross slope would not play a pivotal role and could be ignored since we were designing a fully flat surface with a cross slope of zero. At each side of the bridge, a landing was placed following the criteria that the landings are as wide as the bridge and the landing clear length shall be 60 inches minimally. At each of the landings a ramp is required, so we designed a ramp with a slope no greater than 1:12 with a cross slope no greater than 1:48. Handrails are required on running slopes less than 1:20, but our group decided to place handrails on the entirety of the bridge in order to provide a safe walking environment to all users of the bridges. The surfaces of the handrails do not have burrs or sharp edges as to protect the safety of users and the rails do not rotate in their holders.

4.3 Structural Analysis

Once our group had settled on an aesthetically pleasing design, our next step was to decide which materials would be used. In order to present multiple design options to the LFNR, our group looked at two different materials for the decking of the bridge. As mentioned previously, our group examined both Trex and Southern Yellow Pine No. 1 pressure treated
lumber as a decking material. For the girders and railings the only member sizes calculated were for Southern Yellow Pine No. 1 pressure treated lumber. Our group consulted our survey results as well as our sponsors who have knowledge of the area to determine the uses required for the bridge. The team learned that the trail system is used for horseback riding as well as snowmobiling. All the loads that the bridge would need to carry were researched and gathered. The applicable load combinations were determined based on the LRFD approach. These loads and load combinations were then entered into SAP2000 along with member sizes that seemed typical for a bridge of our type. SAP2000 then provided us with the internal stresses that each member would need to sustain and a member size of sufficient strength was selected. We then needed to go back into the program and adjust the size of the member to check that the extra weight from increasing the member size would not change its compliance.

Trex is a material made from recycled plastics, such as milk bottles. Trex has a longer service life than pressure treated lumber and therefore needs less frequent replacement. However, Trex does have a higher initial cost [Interview with Professor Albano (2014)]. Upon further research into Trex our group discovered that it is only manufactured in two sizes, that would be reasonable for our bridge. Also, the bending strength of Trex is only 500 psi [Trex Company, LLC (2006)]. This value is relatively small compared to the bending strength of Southern Yellow Pine. When our group examined the maximum moment that each Trex member would experience, it was determined that neither of the two sizes would provide sufficient bending strength. These restrictions led our group to conclude that Trex was not an option for the decking material unless the use of the bridge was restricted to only pedestrian use. If this restriction was made our group found that Trex members of size 1” X 6” could be used for the decking and were
sufficient in both bending strength and shear strength. The calculations for this sizing can be seen in Appendix C2.

When our group examined Southern Yellow Pine as a decking material we found much more success. Our group started with a member size of 2” X 6” for the decking. Using the American Wood Council, National Design Specification for Wood Construction our group determined that a Southern Yellow Pine member of this size and under the conditions associated with our bridge geometry and location would be able to sustain a bending moment of 7042.2 lb.-in [American Wood Council (2012)]. From the SAP2000 model it was found that the member would only experience a bending moment of 6167 lb.-in. Therefore, this member size was found to be sufficient in bending. The shear strength of the member was then checked in a similar manner. It was found that a shear value of 1413.5 lb. could be sustained while the maximum shear force experienced was only 803 lb. Therefore, Southern Yellow Pine No. 1 members 2” X 6” were picked for the decking of the bridge. The same process was used to size the girders of the bridge and a girder size of 4” X 16” Southern Yellow Pine No. 1 was chosen. The calculations for this process can be seen in Appendix C3 and Appendix C4.

4.4  Modeling

Results of the modeling process were not limited to the models themselves. Once we started making the bridge assembly in SolidWorks we realized that some member sizes and locations were impractical due to the geometry of the bridge design. We were able to resize members in the model and return to our calculations to ensure the redesigned members had sufficient load carrying capacity. Views of the model can be seen in Appendix D1.

The three dimensional model also allowed us to present our ideas to Professor Albano so he could understand the type of bridge we were envisioning and provide recommendations
during our interview. Our group also created construction drawings, which can be seen in Appendix D2.

4.4.1 Topography

Our group collected the measurements obtained from surveying the Farnsworth - 0.5 Mi. site and formed two and three-dimensional surface plots. Our project team created these plots by inputting 600 data points into Microsoft Excel. While we did not collect this many data points in the field, we made assumptions on several intermittent data points to increase resolution of the topography. To simplify calculations, we assumed a level elevation would exist along the line constructed between any two measured points at the same elevation. Maps created from this exercise can be seen in Appendix G2.

4.5 Erosion

Results from our erosion prevention research indicate that erosion protection mechanisms at the bridge sites should minimize impacts to stream flow, as well as the fish and aquatic life that inhabit the stream and its surroundings. To avoid perching, the channel should utilize the natural substrate of the streambed. Channel dimensions should not be modified in order to prevent alterations to stream flow depth and velocity.

4.5.1 Erosion Control Mechanisms of Interest

Riprap and seeding are the most appropriate and feasible methods of erosion protection for the long-term consequences of emplacing new bridges into the trail system at Cook’s. Riprap is a term used to describe the placement of rocks along the stream bank to protect against erosion. Riprap is a natural solution that will last for a long time because rocks placed along the stream bank “can adjust to the contours of the stream bank and vegetation can grow among the
rocks to provide habitat for wildlife in and above the stream” [Iowa Department of Natural Resources (2006), 33]. Riprap is also affordable because it utilizes naturally available rocks and gravels and is easy to install provided that stream flow is low during the installation process. If we have a rough idea of stream velocity then we can specify the size of rocks to be used according to Figure 11. We should also make sure that the riprap is well graded because it is best for smaller rocks to fill the voids between larger ones.

<table>
<thead>
<tr>
<th>Velocity of stream during high flow</th>
<th>Diameter of rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4 ft./sec</td>
<td>3” – 6” average of 4”</td>
</tr>
<tr>
<td>4-6 ft./sec</td>
<td>4”-12” average of 8”</td>
</tr>
<tr>
<td>6-12 ft./sec</td>
<td>5”-18” average of 14”</td>
</tr>
</tbody>
</table>

Figure 11: Table showing average size of riprap for different stream velocities [Iowa Department of Natural Resources (2006), 34]

The riprap should extend “to the level of a 2-year or 5-year storm” [Iowa Department of Natural Resources (2006), 34] and before the riprap is installed the slope of the stream bank should be reshaped to a maximum slope of two feet horizontal to one foot vertical. Riprap is often used in combination with geogrids that allow for interlocking with earthen material and provide significant structural reinforcement to the stream channel to help prevent erosion. These geogrids should be tucked into the soil and placed below riprap so the textile isn’t seen and forms a matrix with the earthen material. The weight of the rocks that comprise the riprap also stabilizes the geogrid. The other erosion prevention method we should use is seeding which provides physical reinforcement to the stream bank by planting grasses. Seeding is cheap and provides a little bit of reinforcement to the stream bank but should be used in combination with the other methods of erosion prevention described above.
4.6 Cost Estimation

Based on up-to-date pricings of building materials, found from stores such as Home Depot, Lowes, Discount Contractor Supply, The Nutty Company and Fastneal, our group created a cost estimate of the bridge design. Referencing the materials needed from the bridge design, our group discerned that approximately 101 2” x 6” P.T Lumber are needed for the decking, four 18” Sonotubes needed for support, four 4” x 4” P. T Lumber and 65 4” x 16” P.T. Lumber required for post and sides respectively and one 125’ steel cable needed for side and girders. Other materials such as galvanized screws, 3/4” galvanized timber bolts, etc. also contributed to the materials cost analysis. Thus the total estimated material cost calculated was $1,995.90 for one bridge.

In addition to the estimation of material costs, our group included cost estimates for both transportation of materials and maintenance of the bridges. The calculations for all these cost estimates, along with the total cost, can be seen in Appendix F.

4.7 Recommendations

In order for this project to successfully increase accessibility to Cook’s, the bridge proposal would need to be approved by the Lancaster Conservation Commission. To get a better idea of what this approval would require our group performed a mock notice of intent for the Conservation Commission. This included providing plans for the bridges, our steps of design, and two permits that would need to be filed before approval. These permits can be seen in Appendix E. This meeting allowed us to better understand how the process for approval works as well as the additional steps that would need to be taken to get this project approved. Meeting with the Lancaster Conservation Commission also allowed us to better understand the societal and environmental impacts of engineering projects.
4.7.1 Bridge Implementation and Maintenance

Based on our results we have developed the following list of findings and recommendations for the pedestrian bridge designs:

- Construction of new bridges is structurally feasible.
- Construct the bridges in accordance with the construction drawings provided in Appendix D2.
- Use pressure treated southern yellow pine as the material for all structural members.
- Support the structure as outlined in the bridge plans. These involve the use of four concrete columns at each corner of the bridge. A hole slightly in excess of 28” x 28” should be excavated to four feet below grade at each corner to accommodate the use of square footings. Concrete should be cast in Sonotubes and square footing forms on site. The bridge columns should be encased in the concrete to provide anchorage between the bridge and the foundation.
- Install the bridge decking level with the grade and pack soil around the bridge to provide a smooth transition between the soil and the bridge decks.
- Provide temporary erosion controls during the construction process.
- Develop a construction safety plan to protect volunteer workers.
- Coordinate the purchasing and transportation of materials.
- An individual who is capable of assessing the safety and reliability of the structures should check the bridges regularly.

4.7.2 Conservation Commission Recommendations

Our participation in a mock notice of intent hearing revealed several outstanding requirements that must be fulfilled prior to the approval of this project. Along with the required permits and forms, erosion prevention and construction plans must be developed. An erosion and sediment control plan must be created to prevent soil from entering the river and surrounding water resources. This would most likely include the use of hay bales and a silt fence to separate the excavation sites from the waterways. A map of each site that details the location of the
sediment control measures would also need to be included. A rough draft of such a map can be seen in Appendix G4. Finally, a construction sequencing and phasing plan would need to be provided to show the steps of construction and potential impact to natural resources. These plans would also address the challenge of building on both sides of a stream bank and building in an area that cannot be accessed by heavy vehicles.

4.8 Future Recommendations

While the bridges proposed by our group would improve access to Cook’s, there are still many improvements that can be made to increase the use of this beautiful area. These suggestions came from the survey responses we gathered, as well as our own site visits. A future project group or organization could use these projects to further increase the use and accessibility of Cook’s.

4.8.1 Biodiversity & Riparian Ecosystem Study

The purpose of conducting a biodiversity survey is to obtain an inventory of organisms that exist in a given area. By carrying out a biodiversity survey, plants and animal species within Cook’s and its close proximity can be monitored. Information on endangered species and habitats influenced by human activities may also be obtained from survey analysis. Other objectives of a biodiversity survey include making note of invasive species, species variations with seasonal change, and diverse habitats contained in a specific area.

We suggest that the next step is to conduct a biodiversity survey as well as observe the effects of recreational activities on riparian ecosystem of Nashua River. Human activities, especially recreational activities on water can adversely influence natural habitats. Once data is gathered from a biodiversity survey, it should be analyzed for public awareness.
4.8.2 Parking Entrance Improvement

Improvement to the current parking area at the Cook Conservation Area is imperative. The current parking lot is small, filled with potholes, and very uneven. Many users of Cook’s mentioned parking lot improvements in the open ended section of our survey for good reasons. The entrance to the parking area is too narrow for incoming and departing traffic and lacks proper visibility from the road, which is a significant public safety concern. This improvement would greatly increase accessibility to Cook’s.
5.0 Conclusion

Our group’s recommendations to install two replacement pedestrian bridges along the Farnsworth Trail, based on the research investigations and conversations with community stakeholders that our group conducted over the past seven months, constitute our best effort to meet the goal of improving access to the Nashua River. Once the project is approved, construction of the bridges can begin and maintenance procedures suggested can be followed. We also recommend that future IQP groups and the town of Lancaster initiate biodiversity surveys within Cook’s, sponsored by the town of Lancaster (possible project topic for a future group of WPI students), for the purpose of educating and raising public awareness. In addition to these recommendations, we feel that repairs and improvements of the parking entrance to Cook’s will significantly increase accessibility to the site.

Our intent for this project was not only to shine light on the technical aspects of designing structures using the tools of civil engineering, but also learn more about the various economic, environmental, psychological, and social factors that go into the successful introduction of such structures into a community. Before the concrete details of bridge designs were laid out and construction plans chosen, our ultimate goal was to improve public access within Cook’s. Once we reached a decision to build bridges as one method of improving access to the Nashua River, we looked for ways to design a structure that will be both aesthetically compatible with its surrounding environment and will be durable. In doing so, we expanded our understanding to variables that can affect the impact a new bridge would have on the community of Lancaster, such as stability appropriate to intended uses, visual appeal, cost, and adequate provisions for erosion control (both in the construction phase of the project and during the anticipated lifespan of the structure).
Throughout the course of this project, we learned to integrate societal considerations together with those of technology and the environment. By incorporating the needs of the users of Cook’s into our recommendations, if implemented, the number of visitors to the site will increase and the need of those who use the site on a regular basis will be satisfied. Survey data that we collected helped to provide confirmation in the direction we chose to pursue for our project. We also learned how important it is to be sensitive to the environment especially given that our project site was located within an area of critical environmental concern. We gained a new appreciation for the challenges involved in designing a structure that would minimize disruptions to the environment.

Beyond the content of our work, we also acquired invaluable experience in learning to formally present and discuss our work and research before a town’s governing authority. A mock notice of intent hearing before the members of the Lancaster Conservation Commission motivated us to professionalize our work and the presentation of our project. The members of the Lancaster Conservation Commission gave us the extraordinary gift of their time and expertise, by conducting a mock hearing of our project proposal within their official meeting agenda. They then extended the discussion beyond the hearing an additional 45 minutes, to share constructively critical feedback and advice in a conversation that included all the Conservation Commission members present, the four members of the project team, the project advisor, and the project sponsor. This opportunity enlightened us with insights from experts and guidance for further direction of our project.

In the end, this project informed us not only of the technicality and feasibility of designing a bridge, but also of incorporating societal as well and environmental aspects into our design. Overall, we have observed and predicted the wide reaching possibilities of improvements
to be made to Cook’s. We believe that our bridge design will contribute to something greater, and will help sustain the vitality of both the Nashua River and the community of Lancaster in the years to come.
6.0 Bibliography


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Appendix A- Survey

Appendix A1- Survey Form

Figure 12: Survey issued to trail users of the Cook Conservation Area
Appendix A2- Survey Data

Figure 13: Data for the frequency of use of the Cook Conservation Area

Figure 14: Data for the types of use of the Cook Conservation Area
Appendix B- Soils Data

Appendix B1- Farnsworth – 0.5 Mi.

Liquid Limit

<table>
<thead>
<tr>
<th>Container label</th>
<th>Container mass (g)</th>
<th># of blows</th>
<th>Pre-dried mass with container (g)</th>
<th>Post dried mass with Container (g)</th>
<th>Pre-dried mass of Sample (g)</th>
<th>Post dried mass of Sample (g)</th>
<th>Water content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-A</td>
<td>51.4</td>
<td>26.0</td>
<td>60.6</td>
<td>58.3</td>
<td>9.2</td>
<td>6.9</td>
<td>25.0</td>
</tr>
<tr>
<td>1-B</td>
<td>50.7</td>
<td>32.0</td>
<td>65.4</td>
<td>61.6</td>
<td>14.7</td>
<td>10.9</td>
<td>25.9</td>
</tr>
<tr>
<td>1-C</td>
<td>50.5</td>
<td>23.0</td>
<td>63.4</td>
<td>59.9</td>
<td>12.9</td>
<td>9.4</td>
<td>27.1</td>
</tr>
<tr>
<td>1-D</td>
<td>118.7</td>
<td>20.0</td>
<td>131.4</td>
<td>128.1</td>
<td>12.7</td>
<td>9.4</td>
<td>26.0</td>
</tr>
</tbody>
</table>

Figure 15: Data table for the Liquid Limit test for the Farnsworth – 0.5 Mi. Site

The liquid limit is defined as the water content percentage given by the model that would require 25 blows to close the groove made in the sample by the grooving tool.

Liquid Limit (%) = $26$
**Plastic Limit**

<table>
<thead>
<tr>
<th>Container label</th>
<th>Container mass (g)</th>
<th>Pre-dried mass with Container (g)</th>
<th>Post dried mass with Container (g)</th>
<th>Pre-dried mass of sample (g)</th>
<th>Post dried mass of sample (g)</th>
<th>Water content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-E</td>
<td>29.0</td>
<td>35.4</td>
<td>33.7</td>
<td>6.4</td>
<td>4.7</td>
<td>26.6</td>
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<tr>
<td>1-F</td>
<td>48.6</td>
<td>55.3</td>
<td>53.5</td>
<td>6.7</td>
<td>4.9</td>
<td>26.9</td>
</tr>
</tbody>
</table>

Figure 17: Data Table for the Plastic Limit Test of the Farnsworth – 0.5 Mi. Site

The plastic limit is defined as the average of the water contents obtained from the plastic limit tests.

Plastic Limit (%) = 27

Plasticity Index = Liquid Limit - Plastic Limit = 26-27 = -1

Since the Liquid Limit is higher than the Plastic Limit we can say that the soil is non-plastic. Since the fines are non-plastic the fines for this sample they can be classified as **ML**.

**Sieve Analysis**

Preparation type: Oven dried

Mass of total test sample before drying (g): 1000.3

Mass of course material retained by No. 4 sieve (g): 0.0

Mass of fine particle sample plus pan post drying (g): 1203.3

Mass of empty pan (g): 559.2

Mass of fine particle sample added to sieves (g): 644.1

<table>
<thead>
<tr>
<th>Standard Sieve set-Sieve No.</th>
<th>Sieve Size (mm)</th>
<th>Full sieve mass (grams)</th>
<th>Empty sieve mass (grams)</th>
<th>Mass retained on individual sieve (grams)</th>
<th>individual % retained by wt</th>
<th>cumulative % retained</th>
<th>cumulative % passing by wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>4.750</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.360</td>
<td>1237.0</td>
<td>1231.9</td>
<td>5.1</td>
<td>0.79</td>
<td>0.79</td>
<td>99.21</td>
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<td>1154.3</td>
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<td>9.54</td>
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<td>116.6</td>
<td>18.12</td>
<td>28.45</td>
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<td>No. 50</td>
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<td>142.0</td>
<td>22.07</td>
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<td>No.100</td>
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<td>796.3</td>
<td>708.0</td>
<td>88.3</td>
<td>13.72</td>
<td>64.24</td>
<td>35.76</td>
</tr>
<tr>
<td>No. 200</td>
<td>0.075</td>
<td>1036.4</td>
<td>916.5</td>
<td>119.9</td>
<td>18.63</td>
<td>82.87</td>
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<tr>
<td>Pan</td>
<td>0</td>
<td>983.6</td>
<td>873.4</td>
<td>110.2</td>
<td>17.13</td>
<td>100.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 18: Data Table for the Sieve Analysis of the Farnsworth – 0.5 Mi. Site
Figure 19: Gradation Plot for the Farnsworth – 0.5 Mi. site
**Soil Classification**

Since less than 50% of our sample passed through the No. 200 sieve it is considered a coarse-grained soil. Therefore we use the following chart to classify the soil:

![Chart used for classifying coarse grained soil](image)

Figure 20: Chart used for classifying coarse grained soil (same as Figure 9) [American Society for Testing and Materials (2011)]

**Steps of Classification**

1. Less than 50% of the sample passes the No. 200 sieve therefore it is a coarse-grained soil.
2. Our sample has more sand than gravel.
3. Since 17.13% passed the No. 200 sieve we have >12% fines.
4. Since the Atterberg Limit tests determined that the fines of our soil were non-plastic we know the fines are a soil type of ML
5. We know that the sample has < 15% gravel because none of the sample was retained by the No. 4 sieve.
6. Therefore the soil type is: **Silty Sand**
Appendix B2- Farnsworth – 1.5 Mi.

**Liquid Limit**

<table>
<thead>
<tr>
<th>Container label</th>
<th>Container mass (g)</th>
<th># of blows</th>
<th>Pre-dried mass with container (g)</th>
<th>Post dried mass with Container (g)</th>
<th>Pre-dried mass of Sample (g)</th>
<th>Post dried mass of Sample (g)</th>
<th>Water content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-A</td>
<td>48.3</td>
<td>32.0</td>
<td>55.1</td>
<td>53.3</td>
<td>6.8</td>
<td>5.0</td>
<td>26.5</td>
</tr>
<tr>
<td>2-B</td>
<td>114.5</td>
<td>16.0</td>
<td>131.7</td>
<td>127.3</td>
<td>17.2</td>
<td>12.8</td>
<td>25.6</td>
</tr>
<tr>
<td>2-C</td>
<td>107.7</td>
<td>24.0</td>
<td>119.5</td>
<td>116.5</td>
<td>11.8</td>
<td>8.8</td>
<td>25.4</td>
</tr>
<tr>
<td>2-D</td>
<td>68.0</td>
<td>20.0</td>
<td>82.0</td>
<td>78.5</td>
<td>14.0</td>
<td>10.5</td>
<td>25.0</td>
</tr>
</tbody>
</table>

*Figure 21: Data Table for the Liquid Limit Test of the Farnsworth – 1.5 Mi. Site*

The liquid limit is defined as the water content percentage given by the model that would require 25 blows to close the groove made in the sample by the grooving tool.

Liquid Limit (%) = 26


**Plastic Limit**

<table>
<thead>
<tr>
<th>Container label</th>
<th>Container mass (g)</th>
<th>Pre-dried mass with Container (g)</th>
<th>Post dried mass with Container (g)</th>
<th>Pre-dried mass of sample (g)</th>
<th>Post dried mass of sample (g)</th>
<th>Water content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-E</td>
<td>54.6</td>
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<td>59.8</td>
<td>6.8</td>
<td>5.2</td>
<td>23.5</td>
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<tr>
<td>2-F</td>
<td>68.8</td>
<td>75.1</td>
<td>73.4</td>
<td>6.3</td>
<td>4.6</td>
<td>27.0</td>
</tr>
</tbody>
</table>

Figure 23: Data Table for the Plastic Limit Test of the Farnsworth – 1.5 Mi. site

The plastic limit is defined as the average of the water contents obtained from the plastic limit tests.

Plastic Limit (%) = 25

Plasticity Index = Liquid Limit - Plastic Limit = 26-25 = 1

Since the Plasticity Index is less than 3 the soil is non-plastic.

Since the fines are non-plastic for this sample they can be classified as ML.

**Sieve Analysis**

**Preparation type:** Oven dried

**Mass of total test sample before drying (g):** 1000.4

**Mass of course material retained by No. 4 sieve (g):** 0.0

**Mass of fine particle sample plus pan post drying (g):** 1353.0

**Mass of empty pan (g):** 566.4

**Mass of fine particle sample added to sieves (g):** 786.6

<table>
<thead>
<tr>
<th>Standard Sieve set- Sieve No.</th>
<th>Sieve Size (mm)</th>
<th>Full sieve mass (grams)</th>
<th>Empty sieve mass (grams)</th>
<th>Mass retained on individual sieve(grams)</th>
<th>individual % retained by wt</th>
<th>cumulative % retained</th>
<th>cumulative % passing by wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>4.750</td>
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<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>No. 8</td>
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<td>1232.7</td>
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<td>0.09</td>
<td>99.91</td>
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<td>1048.4</td>
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<td>9.98</td>
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<td>No.100</td>
<td>0.150</td>
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<td>708.0</td>
<td>340.4</td>
<td>43.21</td>
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<td>43.39</td>
</tr>
<tr>
<td>No. 200</td>
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<td>1184.5</td>
<td>916.0</td>
<td>268.5</td>
<td>34.09</td>
<td>90.69</td>
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<tr>
<td>Pan</td>
<td>0</td>
<td>946.5</td>
<td>873.2</td>
<td>73.3</td>
<td>9.31</td>
<td>100.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Total 787.70

Figure 24: Data Table for the Sieve Analysis of the Farnsworth – 1.5 Mi. Site
Figure 25: Gradation Plot for the Farnsworth – 1.5 Mi. site
**Soil Classification**

Since less than 50% of our sample passed through the No. 200 sieve it is considered a coarse-grained soil. Therefore we use the following chart to classify the soil:

![Chart for classifying coarse grained soil](image)

**Steps of Classification**

1. Less than 50% of the sample passes the No. 200 sieve therefore it is a coarse-grained soil.
2. Our sample has more sand than gravel.
3. Since 9.31% passed the No. 200 sieve we have 5-12% fines.
4. We calculate $C_U$ and $C_C$ from data collected off the gradation plot and see if $C_U < 6$ and if $1 <= C_C <= 3$:
   a. $C_U = D_{60}/D_{10}$
b. \( C_C = (D_{30})^2 / (D_{10} \times D_{60}) \)

c. \( D_{60} = 0.2 \)

d. \( D_{30} = 0.12 \)

e. \( D_{10} = 0.075 \)

f. \( C_U = 2.67 < 6 \)

g. \( C_C = 0.96 < 1 \)

5. Since the Atterberg Limit tests determined that the fines of our soil were non-plastic we know the fines are a soil type of ML

6. We know that the sample has < 15% gravel because none of the sample was retained by the No. 4 sieve.

7. Therefore the soil type is: **Poorly graded sand with silt**
Appendix C- Structural Analysis

Appendix C1 - Preliminary Calculations

**Loads:**

Pedestrian live load: 90 PSF per AASHTO LRFD 2009

Vehicle live load: Based on Polaris Sportsman Touring XP 1000
- Dry, unloaded ATV can weigh up to 800 lbs
- Weight of rider: 250 lbs
- Weight of gear: 150 lbs
- From LRFD Guide Specifications for the design of Pedestrian Bridges, 80% of load placed on rear axle of vehicle: 70 lbs. 1300 lb = 960 lbs
- Common ATV tires: 26 x 11-4; Section width = 11"
- Axle wheel spacing: Width of ATV = 48"
- Axle wheel spacing: 48" - (2 x 11") = 37" = Axle wheel spacing

For rear axle, load per tire = 960 lbs / 2 = 480 lbs

Based on 5' 6" Deck Width

\[
\begin{align*}
0.48K & \quad 0.48K \\
\delta y & = 11.5'' \\
\delta y & = 51.5'' \\
X (in) & \\
A & \quad E_x = 0.48 - V_1 \\
& \quad V_1 = 0.48 K \\
\sum \sigma_{E_x} = 0.48 - 0.48 - V_1 & = 7 V_2 = 0 \\
\sum \sigma_{E_y} = 0.48 x - M_1 & = 0.48 x - 14.4 \\
M_1 & = 0.48 x \quad 0 < x < 14.4 \\
\sum \sigma_{E_x} = 0.48 - 0.48 - V_2 & = 7 V_2 = 0 \\
\sum \sigma_{E_y} = 0.48 x - 0.48(x - 14.5) - M_2 & = 0.48 \\
M_2 & = 6.9 \, k \cdot in \quad 14.5 < x < 51.5 \\
\sum \sigma_{E_x} = 0.48 - 0.48 - V_3 & = 7 \, V_3 = 0.48 K \\
\sum \sigma_{E_y} = 0.48 x - 0.48(x - 14.5) - 0.48(x - 51.5) - M_3 & = 0 \\
M_3 & = -0.48 x + 6.9 x - 0.48 x + 24.72 \quad M_2 = 0 \\
M_3 & = -0.48 x + 131.68 \quad 51.5 < x < 66 \\
& \quad 6.9 k \cdot in
\end{align*}
\]
Pedestrian Calculations - Assuming 2x6 decking

90 PSF Live load x 5.5" = 41.25 Plf

\[ 41.25 \text{ Plf} = 0.003438 \text{ k/in} \]

41.25 lb x 5.5 ft = 227 lb acting at center

\[ A_y + 0.0567 - 0.1134 = 0 \]
\[ A_y = 0.0567 \text{ k} \]

\[ \Sigma F_y = A_y + B_y - 0.1134 \]
\[ B_y = 0 \]

\[ 66B_y = 7.49 \]
\[ 0.1135 \text{ k} \]

\[ \Sigma M_A = 0 = 0.1135" - B_y \cdot 66" \]

\[ 0.1135 \text{ k} \]

\[ A_y = 0.0567 \text{ k} \]

Area under steel:
\[ \frac{1}{2} \cdot 23 \cdot 0.1135 \]

\[ M_{cut} = 0 = 0.1135\bar{x} - M_1 - 0.003438\bar{x}^2 \]

\[ M_1 = 0.001719 \bar{V}^2 + 0.1135 \bar{x} \]

\[ V_1 = 0.1135 \text{ k} - 0.003438\bar{x} \]

\[ M_{max} = 1.875 \text{ k/in} \leq 156 \text{ lb-ft} \]

\[ 0 < x < 66 \]
Snow Load Calculations
Per MA Building Code
780CMR Chap. 16
Lancaster MA Snow Load = 55 PSF
55 PSF Snow load \times \frac{5.5''}{12''/ft} = 25.21 \text{ PSF} = 0.002101 \text{ k/lin ft}

\begin{align*}
25.21 \frac{\text{PSF}}{\text{lin ft}} \times 5.5'' &= 138.41 \text{ k}\NO_p \\
0.13866 k &= \\
A_y &= B_y = 0.0694 k
\end{align*}

\begin{align*}
\sum M_{V_1} &= 0 = 0.0694x - 0.002101x^2 - \frac{x}{2} - m_1 \\
m_1 &= -0.001051x^2 + 0.0694x \quad 0 < x < 66
\end{align*}

\begin{align*}
\sum F_y &= 0 = 0.0694 - 0.002101x - V_1 \\
V_1 &= 0.002101x + 0.0694 \quad 0 < x < 66
\end{align*}
Checking if 18" diameter sonotubes provide enough area to transfer the weight of the bridge and to loads to the soil. The sonotubes will be embedded 4' into the soil.

For both silts, sand & pozzolans gravel, sand and silts:

\[ q_a = 1500 \text{ psf} \quad \text{Code of Federal Regulations} \]

 Loads per each sonotube

Wood = \( k_1 (2100 \text{ lb}) = 525 \text{ lb} \)

PEO = \( k_1 (90 \frac{15}{2}) (55', 20') = 2475 \text{ lb} \)

Sno = \( k_1 (50 \frac{15}{2}, 2) (55', 20') = 1375 \text{ lb} \)

Hoc = \( k_1 (1000 \text{ lb}) = 250 \text{ lb} \)

ATV = \( k_2 (600 \text{ lb}) = 150 \text{ lb} \)

Snowmobile = \( k_1 (800 \text{ lb}) = 200 \text{ lb} \)

Concrete = \( 150 \frac{15}{2}, 1 \cdot \left( \frac{12}{4} \right)^2 \frac{1}{4} = 1070 \text{ lb} \)

Unfactored load combinations

\( D + S + PEO = 1070 + 525 + 1375 + 2475 = 5425 \text{ lb} \quad \text{critical case} \)

\( D + S + Sno = 1070 + 525 + 1375 + 200 = 3100 \text{ lb} \)

\( D + Hoc = 1070 + 525 + 250 = 1875 \text{ lb} \)

\( D + ATV = 1070 + 525 + 150 = 1775 \text{ lb} \)

Required area

\[ A_{req} = \frac{W}{q_a} = \frac{5425 \text{ lb}}{1500 \text{ psf}} = 3.62 \text{ ft}^2 \]

Actual given

\[ A = \left( \frac{18}{4} \right)^2 \frac{1}{4} = 256.5 \text{ in}^2 \cdot \left( \frac{12}{4} \right)^2 = 1.767 \text{ ft}^2 < 3.62 \text{ ft}^2 \]

This sonotube size does not work with our sonotubes.
USING a square foot: 28" x 28" footing applied to a 12" diameter sonotube

- 28" x 28" footing
- 12" diameter sonotube
- W = 1500 psf

**Load per footing**

- Wood = 525 lb
- Pedestrian = 2475 lb
- Snow = 1375 lb
- Horse = 250 lb
- ATV = 150 lb
- Snowmobile = 200 lb

**Concrete = 150 \frac{\text{lb}}{\text{ft}^2} \left(4\frac{\text{ft}}{12}\right)^2 + \left(\frac{28\frac{\text{in}}{12}}{12}\right)^2 = 1823 \text{ lb}

**Uncalculated load combination**

- D+S+Ped = 525 + 1823 + 1375 + 2475 = 6198 lb
- Critical case
- D+S+Snow = 525 + 1823 + 1375 + 200 = 3923 lb

- 0 + H = 1823 + 525 + 250 = 2598 lb
- 0 + ATV = 1823 + 525 + 150 = 2498 lb

**Required area**

- \text{Area} = \frac{W}{L} = \frac{6198}{1500} = 4.132 \text{ ft}^2

**Actual area**

- A = \left(28\frac{\text{in}}{12}\right)^2 + \left(\frac{150}{12}\right)^2 = 5.441 \text{ ft}^2 > 4.132 \text{ ft}^2

This footing size works.

**Use a 12" diameter sonotube along with a 28" x 28" square footing.**
Material: TREX

Even SFC Analysis

Maximum moment expected = 6.166 k-in (Deer + horse) (@ x=33")

Maximum shear expected = 0.803 k (Deer + horse) (@ x=0.875"

Mechanical Properties (From TREX booklet)

E=175,000 psi

Design = 60 PCP

<table>
<thead>
<tr>
<th>Design Values</th>
<th>Ultimate Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 psi</td>
<td>3280 psi</td>
</tr>
<tr>
<td>360 psi</td>
<td>1761 psi</td>
</tr>
</tbody>
</table>

Section properties

Nominal size: 1" x 6"

Actual size: 1" x 3.75"

I = \( \frac{1}{12} bh^3 = \frac{1}{12} (5.5)(1)^3 = 0.4458 \text{ in}^4 \)

C = \( \frac{h}{2} = \frac{5.5}{2} = 2.75 \text{ in} \)

\[ F_b = \frac{M}{I} \]

for Max. Allowable Moment

\[ M_{allow} = \frac{F_b 0.4458}{C} \]

\[ M_{allow} = \frac{500(0.4458)}{0.5} = 0.4458 \text{ k-in} < 6.166 \text{ k-in} \]

This section is not acceptable.

Section properties

Nominal size: 2" x 6"

Actual size: 1.375" x 5.5"

I = \( \frac{1}{12} bh^3 = \frac{1}{12} (5.5)(1.375)^3 = 1.19 \text{ in}^4 \)

C = \( \frac{h}{2} = \frac{5.5}{2} = 2.75 \text{ in} \)

\[ M_{allow} = \frac{F_b 1.19}{C} = \frac{500(1.19)}{2.75} = 0.865 \text{ k-in} < 6.166 \text{ k-in} \]

This section is not acceptable.

Since these sections do not have a high enough bending strength for these loading conditions we have decided TREX decki would only be suitable if vehicles and horses are prohibited from using the bridge.

Calculations for this scenario can be seen on the next page.
Material: TREX (ATV's, snowmobiles, horses prohibited from using the bridge). 

Even span Analysis:
Maximum moment expected = 0.331 k·ft (Dead + Snow + Pedestrian) \( \text{@} x = 22" \text{ & } x = 50" \)
Maximum shear expected = 0.090 k (Dead + Snow + Pedestrian) \( \text{@} x = 22" \text{ & } x = 50" \)

Mechanical properties (From TREX website):
- \( E = 175,000 \) psi
- \( \rho = 60 \)pcf

<table>
<thead>
<tr>
<th>Section Properties</th>
<th>Ultimate Values</th>
<th>Design Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending strength (( F_b ))</td>
<td>3260 psi</td>
<td>( F_b = 5000 ) psi</td>
</tr>
<tr>
<td>Shear strength (( F_s ))</td>
<td>1761 psi</td>
<td>( F_s = 3600 ) psi</td>
</tr>
</tbody>
</table>

Design Applied Load: 0.458 k·ft

\[ V = \frac{F \cdot L}{I} \]

Design shear: 0.335 k·ft

\[ V = \frac{V_{allow}}{\gamma} \]

\[ V_{allow} = \frac{F_b I}{\gamma} \]

<table>
<thead>
<tr>
<th>Section</th>
<th>Moment of Inertia</th>
<th>Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; x 6&quot;</td>
<td>0.458 in²</td>
<td>3600 psi</td>
</tr>
</tbody>
</table>

This section would be in bending for the Scenario

If we prohibit ATV's, snowmobiles, horses, and other heavy vehicles or animals from using the bridge then we would use a design size of:

1" x 6" TREX Transcend or TREX Enhance
Material: No. 1 Southern Yellow Pine
Mechanical Properties (From American Wood Council)
F = 1,600,000 PSI
Density = 55 lb/ft³

Design Values
Bending Stress (Fb) = 1350 PSI
Shear Stress (Fv) = 175 PSI

Section Properties
Nominal Size: 2" x 6"
Actual Size: 1.95" x 5.75"
I = \( \frac{1}{12} bh^3 = \frac{1}{12} (5.5)(1.5)^3 = 1.55 \text{ in}^4 \)
C = \( \frac{1}{4}h = \frac{1}{4}(5.5) = 1.375 \text{ in} \)
T = 5.5 in
A = bh = 2.6 (5.5)(1.5) = 16.5 in²

From SAP Analysis (for this section & material)
Maximum Moment Exponent = 0.167 K-in (Dowel + Hardware) @ A point of the bending
Maximum Shear Exponent = 0.803 K (Dowel + Hardware) @ a typical position

Bending

\[ M_{max} = \frac{F_b I}{C} \]

From National Design Specification for Wood Construction:
\[ F_b = F_{b0} \cdot C_m \cdot C_t \cdot C_L \cdot C_F \cdot C_w \cdot C_r \cdot 2.5 \cdot 0.85 \cdot 1.0 \]
\[ F_{b0} = 1350 \]
\[ C_m = 0.85 \]
\[ C_t = 1 \]
\[ C_L = 1 \]
\[ C_F = 1.0 \]
\[ C_w = 1.0 \]
\[ C_r = 1.0 \]
\[ \lambda = 0.8 \]
\[ F_b = 1350 \cdot 0.85 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 2.5 \cdot 1.0 \cdot 0.85 \cdot 0.8 \Rightarrow 34,107.5 \text{ PSI} \]
\[ M_{max} = \frac{34,107.5 \text{ PSI} \cdot 1.55 \text{ in}²}{0.75} = 704,222 \text{ lb-in} = 7,042.2 \text{ K-in} > 6,167 \text{ K-in} \]

Shear

\[ V_{max} = \frac{F_v I}{C} \]

From National Design Specification for Wood Construction:
\[ F_v = F_{v0} \cdot C_m \cdot C_t \cdot C_L \cdot C_F \cdot C_w \cdot 2.88 \cdot 0.75 \cdot 1.0 \]
\[ F_{v0} = 175 \text{ PSI} \]
\[ C_m = 0.85 \]
\[ C_t = 1 \]
\[ C_L = 1 \]
\[ C_F = 1.0 \]
\[ F_v = 175 \cdot 0.85 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 2.88 \cdot 0.75 \cdot 1.0 = 257 \text{ PSI} \]
\[ V_{max} = \frac{257 \cdot 1.55 \cdot 5.5}{1.55} = 1413.5 \text{ in-lb} = 141.11 \text{ K} > 140.8 \text{ K} \]

2" x 6" No. 1 Southern Yellow Pine Pressure-Treated
$$S_{crit} = \frac{F_V}{\ell_T}$$

For a given allowable stress, \( F_V = F_v \)

$$\therefore F_V = \frac{F_v \ell_T}{\ell}$$

From Nuthall's design procedure to wood columns:

$$F_v = F_v \cdot C_m \cdot C_t \cdot C_y \cdot 2.88 \cdot 0.75 \cdot x$$

- \( F_v = 175 \) Psi
- \( C_m = 0.85 \)
- \( C_t = 1 \)
- \( C_y = 1 \)
- \( x = 0.8 \)

$$F_v = 175 \text{ psi} \cdot 0.85 \cdot 1 \cdot 0.8 \cdot 2.88 \cdot 0.75 = 257.04 \text{ psi}$$

$$V_{allow} = \frac{257.04 \cdot 1086.15 \cdot 3.5}{103.11} = 9296.15 = 9.296 \text{ kips} > 2.814 \text{ kips}$$

Since this section works in shear, this section works in both bending & shear. We will use the smaller of our given:

**4 x 12" No. 1 Southern Yellow Pine Pressure Treated Lumber**
Appendix D - Models and Drawings

Appendix D1 - Model Views

Isometric-View
Top-View

Section-View
Projected Bridge-View
Appendix D2- Drawings

General Notes and Specifications:

1. Lumber for deck, railings, and orders shall be pressure treated southern yellow pine.
2. All holes shall be pre-drilled for proper placement of fasteners.
3. Hand holes shall be made smooth by sanding.

Connections:
1. All bolts, anchors, nuts, and hardware shall be ASTM A307 galvanized.
2. Use washers on both sides of fasteners.

Lumber:
- 3 x 6 x 14" lumber for formations
- 4 x 6 x 14" lumber for board forms
- 3/4" diameter galvanized wall plates
- Interference with board forms and non-support grids, etc.

Architectural Steel Cables for guardrail:
- 3 x 6 x 14" lumber for deck between 12" spacing
- 1/4" diameter galvanized turnbuckles for guardrail

Gage:
- 1/4" diameter galvanized turnbuckles for guardrail
- 3/4" diameter galvanized turnbuckles for guardrail

20" spacing for guardrail

Cook Conservation Area
Lunenburg Rd.
Lancaster, MA

Bridge Plan

Project:       Date:       Scale:       Approved by:

90
Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

WPA Form 3 – Notice of Intent
Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

A. General Information

1. Project Location (Note: electronic filers will click on button to locate project site):
   - Lunenburg Rd
   - Lancaster 01523
   - a. Street Address
   - b. City/Town
   - c. Zip Code
   - Latitude and Longitude:
     - 42.5
     - -71.69
   - d. Latitude
   - e. Longitude
   - f. Assessors Map/Plat Number
   - g. Parcel/Lot Number

2. Applicant:
   - Hannah
   - a. First Name
   - Lee
   - b. Last Name
   - WPI Interactive Qualifying Project Group-Improving Access to Nashua River
   - c. Organization
   - 100 Institute Road
   - d. Street Address
   - Worcester 01609
   - e. City/Town
   - f. State
   - g. Zip Code
   - 508-579-2609
   - h. Phone Number
   - hlee15@wpi.edu
   - i. Fax Number
   - j. Email Address

3. Property owner (required if different from applicant): □ Check if more than one owner
   - a. First Name
   - b. Last Name
   - Lancaster Conservation Commission
   - c. Organization
   - 695 Main St
   - d. Street Address
   - Lancaster 01523
   - e. City/Town
   - f. State
   - g. Zip Code
   - 978-365-3326 978-368-4009
   - h. Phone Number
   - i. Fax Number
   - j. Email address

4. Representative (if any):
   - Hannah
   - a. First Name
   - Lee
   - b. Last Name
   - Worcester Polytechnic Institute
   - c. Company
   - 100 Institute Road
   - d. Street Address
   - Worcester 01609
   - e. City/Town
   - f. State
   - g. Zip Code
   - 508-579-2609
   - h. Phone Number
   - i. Fax Number
   - j. Email address

5. Total WPA Fee Paid (from NOI Wetland Fee Transmittal Form):
   - $ 6291.80
   - $ 3133.40
   - $ 3158.4
   - a. Total Fee Paid
   - b. State Fee Paid
   - c. City/Town Fee Paid
A. General Information (continued)

6. General Project Description:

Constructing bridges at two different sites on the Cook Conservation Area to provide better trail access to the community members of Lancaster.

7a. Project Type Checklist: (Limited Project Types see Section A. 7b.)

1. ☐ Single Family Home
   2. ☑ Residential Subdivision
3. ☒ Commercial/Industrial
   4. ☐ Dock/Pier
5. ☐ Utilities
   6. ☐ Coastal engineering Structure
7. ☐ Agriculture (e.g., cranberries, forestry)
   8. ☒ Transportation
9. ☐ Other

7b. Is any portion of the proposed activity eligible to be treated as a limited project (including Ecological Restoration Limited Project) subject to 310 CMR 10.24 (coastal) or 310 CMR 10.53 (inland)?

1. ☐ Yes  ☑ No
   If yes, describe which limited project applies to this project. (See 310 CMR 10.24 and 10.53 for a complete list and description of limited project types)

2. Limited Project Type

If the proposed activity is eligible to be treated as an Ecological Restoration Limited Project (310 CMR 10.24(8), 310 CMR 10.53(4)), complete and attach Appendix A: Ecological Restoration Limited Project Checklist and Signed Certification.

8. Property recorded at the Registry of Deeds for:

   Worcester
   a. County
   b. Certificate # (if registered land)
   c. Book
   d. Page Number

B. Buffer Zone & Resource Area Impacts (temporary & permanent)

1. ☐ Buffer Zone Only – Check if the project is located only in the Buffer Zone of a Bordering Vegetated Wetland, Inland Bank, or Coastal Resource Area.

2. ☒ Inland Resource Areas (see 310 CMR 10.54-10.58; if not applicable, go to Section B.3, Coastal Resource Areas).

Check all that apply below. Attach narrative and any supporting documentation describing how the project will meet all performance standards for each of the resource areas altered, including standards requiring consideration of alternative project design or location.
## B. Buffer Zone & Resource Area Impacts (temporary & permanent) (cont’d)

<table>
<thead>
<tr>
<th>Resource Area</th>
<th>Size of Proposed Alteration</th>
<th>Proposed Replacement (if any)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ☑ Bank</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>b. ☐ Bordering Vegetated Wetland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. ☐ Land Under Waterbodies and Waterways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. ☐ Bordering Land Subject to Flooding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. ☐ Isolated Land Subject to Flooding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. ☑ Riverfront Area</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For all projects affecting other Resource Areas, please attach a narrative explaining how the resource area was delineated.

<table>
<thead>
<tr>
<th>Resource Area</th>
<th>Size of Proposed Alteration</th>
<th>Proposed Replacement (if any)</th>
</tr>
</thead>
<tbody>
<tr>
<td>d. ☐ Bordering Land Subject to Flooding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. ☐ Isolated Land Subject to Flooding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. ☑ Riverfront Area</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Width of Riverfront Area (check one):
   - ☐ 25 ft. - Designated Densely Developed Areas only
   - ☑ 100 ft. - New agricultural projects only
   - ☑ 200 ft. - All other projects

3. Total area of Riverfront Area on the site of the proposed project: 200 square feet

4. Proposed alteration of the Riverfront Area:

   600
   a. total square feet
   b. square feet within 100 ft.
   c. square feet between 100 ft. and 200 ft.

5. Has an alternatives analysis been done and is it attached to this NOI? ☑ Yes ☐ No

6. Was the lot where the activity is proposed created prior to August 1, 1996? ☑ Yes ☐ No

3. ☐ Coastal Resource Areas: (See 310 CMR 10.25-10.35)
B. Buffer Zone & Resource Area Impacts (temporary & permanent) (cont’d)

Check all that apply below. Attach narrative and supporting documentation describing how the project will meet all performance standards for each of the resource areas altered, including standards requiring consideration of alternative project design or location.

<table>
<thead>
<tr>
<th>Resource Area</th>
<th>Size of Proposed Alteration</th>
<th>Proposed Replacement (if any)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ☐ Designated Port Areas</td>
<td>Indicate size under Land Under the Ocean, below</td>
<td></td>
</tr>
<tr>
<td>b. ☐ Land Under the Ocean</td>
<td>1. square feet</td>
<td>2. cubic yards dredged</td>
</tr>
<tr>
<td>c. ☐ Barrier Beach</td>
<td>Indicate size under Coastal Beaches and/or Coastal Dunes below</td>
<td></td>
</tr>
<tr>
<td>d. ☐ Coastal Beaches</td>
<td>1. square feet</td>
<td>2. cubic yards beach nourishment</td>
</tr>
<tr>
<td>e. ☐ Coastal Dunes</td>
<td>1. square feet</td>
<td>2. cubic yards dune nourishment</td>
</tr>
<tr>
<td>f. ☐ Coastal Banks</td>
<td>1. linear feet</td>
<td></td>
</tr>
<tr>
<td>g. ☐ Rocky Intertidal Shores</td>
<td>1. square feet</td>
<td></td>
</tr>
<tr>
<td>h. ☐ Salt Marshes</td>
<td>1. square feet</td>
<td>2. sq ft restoration, rehab., creation</td>
</tr>
<tr>
<td>i. ☐ Land Under Salt Ponds</td>
<td>1. square feet</td>
<td>2. cubic yards dredged</td>
</tr>
<tr>
<td>j. ☐ Land Containing Shellfish</td>
<td>1. square feet</td>
<td></td>
</tr>
<tr>
<td>k. ☐ Fish Runs</td>
<td>Indicate size under Coastal Banks, inland Bank, Land Under the Ocean, and/or inland Land Under Waterbodies and Waterways, above</td>
<td></td>
</tr>
<tr>
<td>l. ☐ Land Subject to Coastal Storm Flowage</td>
<td>1. cubic yards dredged</td>
<td></td>
</tr>
</tbody>
</table>

4. ☐ Restoration/Enhancement
   If the project is for the purpose of restoring or enhancing a wetland resource area in addition to the square footage that has been entered in Section B.2.b or B.3.h above, please enter the additional amount here.
   a. square feet of BVW     b. square feet of Salt Marsh

5. ☒ Project Involves Stream Crossings
   -2-
   a. number of new stream crossings  b. number of replacement stream crossings
C. Other Applicable Standards and Requirements

☐ This is a proposal for an Ecological Restoration Limited Project. Skip Section C and complete Appendix A: Ecological Restoration Notice of Intent – Required Actions (310 CMR 10.11).

Streamlined Massachusetts Endangered Species Act/Wetlands Protection Act Review

1. Is any portion of the proposed project located in Estimated Habitat of Rare Wildlife as indicated on the most recent Estimated Habitat Map of State-Listed Rare Wetland Wildlife published by the Natural Heritage and Endangered Species Program (NHESP)? To view habitat maps, see the Massachusetts Natural Heritage Atlas or go to http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/priority_habitat/online_viewer.htm.

   a. ☐ Yes  ☒ No

   If yes, include proof of mailing or hand delivery of NOI to:
   Natural Heritage and Endangered Species Program
   Division of Fisheries and Wildlife
   1 Rabbit Hill Road
   Westborough, MA 01581
   Phone: (508) 389-6360

   b. Date of map

   If yes, the project is also subject to Massachusetts Endangered Species Act (MESA) review (321 CMR 10.18). To qualify for a streamlined, 30-day, MESA/Wetlands Protection Act review, please complete Section C.1.C, and include requested materials with this Notice of Intent (NOI); OR complete Section C.1.d, if applicable. If MESA supplemental information is not included with the NOI, by completing Section 1 of this form, the NHESP will require a separate MESA filing which may take up to 90 days to review (unless noted exceptions in Section 2 apply, see below).

1c. Submit Supplemental Information for Endangered Species Review

   1. ☒ Percentage/acreage of property to be altered:

      (a) within wetland Resource Area 2% percentage/acreage
      (b) outside Resource Area 0% percentage/acreage

   2. ☐ Assessor's Map or right-of-way plan of site

   2. ☒ Project plans for entire project site, including wetland resource areas and areas outside of wetlands jurisdiction, showing existing and proposed conditions, existing and proposed tree/vegetation clearing line, and clearly demarcated limits of work **

      (a) ☒ Project description (including description of impacts outside of wetland resource area & buffer zone)
      (b) ☒ Photographs representative of the site

* Some projects not in Estimated Habitat may be located in Priority Habitat, and require NHESP review (see http://www.mass.gov/dfwele/dfw/nhesp/nhesp.htm, regulatory review tab). Priority Habitat includes habitat for state-listed plants and strictly upland species not protected by the Wetlands Protection Act.

** MESA projects may not be segmented (321 CMR 10.16). The applicant must disclose full development plans even if such plans are not required as part of the Notice of Intent process.
C. Other Applicable Standards and Requirements (cont’d)

(c) ☐ MESA filing fee (fee information available at http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/mesa/mesa_fee_schedule.htm). Make check payable to “Commonwealth of Massachusetts - NHESP” and mail to NHESP at above address.

Projects altering 10 or more acres of land, also submit:

(d) ☐ Vegetation cover type map of site

(e) ☐ Project plans showing Priority & Estimated Habitat boundaries

(f) OR Check One of the Following

1. ☒ Project is exempt from MESA review. Attach applicant letter indicating which MESA exemption applies. (See 321 CMR 10.14, http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/mesa/mesa_exemptions.htm; the NOI must still be sent to NHESP if the project is within estimated habitat pursuant to 310 CMR 10.37 and 10.59.)

2. ☐ Separate MESA review ongoing.  
   a. NHESP Tracking #  
   b. Date submitted to NHESP

3. ☐ Separate MESA review completed.  
   Include copy of NHESP “no Take” determination or valid Conservation & Management Permit with approved plan.

3. For coastal projects only, is any portion of the proposed project located below the mean high water line or in a fish run?
   a. ☒ Not applicable – project is in inland resource area only
   b. ☐ Yes ☐ No  If yes, include proof of mailing or hand delivery of NOI to either:

   South Shore - Cohasset to Rhode Island, and the Cape & Islands:  
   Division of Marine Fisheries - Southeast Marine Fisheries Station  
   Attn: Environmental Reviewer  
   1213 Purchase Street – 3rd Floor  
   New Bedford, MA 02740-6694

   North Shore - Hull to New Hampshire:  
   Division of Marine Fisheries - North Shore Office  
   Attn: Environmental Reviewer  
   30 Emerson Avenue  
   Gloucester, MA 01930

Also if yes, the project may require a Chapter 91 license. For coastal towns in the Northeast Region, please contact MassDEP’s Boston Office. For coastal towns in the Southeast Region, please contact MassDEP’s Southeast Regional Office.
C. Other Applicable Standards and Requirements (cont’d)

4. Is any portion of the proposed project within an Area of Critical Environmental Concern (ACEC)?
   a. ☒ Yes ☐ No
      If yes, provide name of ACEC (see instructions to WPA Form 3 or MassDEP Website for ACEC locations). Note: electronic filers click on Website.
      Central Nahsua Valley
   b. ACEC

5. Is any portion of the proposed project within an area designated as an Outstanding Resource Water (ORW) as designated in the Massachusetts Surface Water Quality Standards, 314 CMR 4.00?
   a. ☐ Yes ☒ No

6. Is any portion of the site subject to a Wetlands Restriction Order under the Inland Wetlands Restriction Act (M.G.L. c. 131, § 40A) or the Coastal Wetlands Restriction Act (M.G.L. c. 130, § 105)?
   a. ☐ Yes ☒ No

7. Is this project subject to provisions of the MassDEP Stormwater Management Standards?
   a. ☒ Yes. Attach a copy of the Stormwater Report as required by the Stormwater Management Standards per 310 CMR 10.05(6)(k)-(q) and check if:
      1. ☐ Applying for Low Impact Development (LID) site design credits (as described in Stormwater Management Handbook Vol. 2, Chapter 3)
      2. ☐ A portion of the site constitutes redevelopment
      3. ☐ Proprietary BMPs are included in the Stormwater Management System.
   b. ☐ No. Check why the project is exempt:
      1. ☐ Single-family house
      2. ☒ Emergency road repair
      3. ☐ Small Residential Subdivision (less than or equal to 4 single-family houses or less than equal to 4 units in multi-family housing project) with no discharge to Critical Areas.

D. Additional Information

☐ This is a proposal for an Ecological Restoration Limited Project. Skip Section D and complete Appendix A: Ecological Restoration Notice of Intent – Minimum Required Documents (310 CMR 10.12).

Applicants must include the following with this Notice of Intent (NOI). See instructions for details.

Online Users: Attach the document transaction number (provided on your receipt page) for any of the following information you submit to the Department.

1. ☐ USGS or other map of the area (along with a narrative description, if necessary) containing sufficient information for the Conservation Commission and the Department to locate the site. (Electronic filers may omit this item.)

2. ☐ Plans identifying the location of proposed activities (including activities proposed to serve as a Bordering Vegetated Wetland [BVW] replication area or other mitigating measure) relative to the boundaries of each affected resource area.
D. Additional Information (cont’d)

3. [ ] Identify the method for BVW and other resource area boundary delineations (MassDEP BVW Field Data Form(s), Determination of Applicability, Order of Resource Area Delineation, etc.), and attach documentation of the methodology.

4. [ ] List the titles and dates for all plans and other materials submitted with this NOI.

   Bridge Replacement to Improve Access to the Nashua River
   a. Plan Title
   Worcester Polytechnic IQP Group
   b. Prepared By
   c. Signed and Stamped by
   d. Final Revision Date
   e. Scale
   f. Additional Plan or Document Title
   g. Date

5. [ ] If there is more than one property owner, please attach a list of these property owners not listed on this form.

6. [ ] Attach proof of mailing for Natural Heritage and Endangered Species Program, if needed.

7. [ ] Attach proof of mailing for Massachusetts Division of Marine Fisheries, if needed.

8. [ ] Attach NOI Wetland Fee Transmittal Form

9. [ ] Attach Stormwater Report, if needed.

E. Fees

1. [ ] Fee Exempt: No filing fee shall be assessed for projects of any city, town, county, or district of the Commonwealth, federally recognized Indian tribe housing authority, municipal housing authority, or the Massachusetts Bay Transportation Authority.

   Applicants must submit the following information (in addition to pages 1 and 2 of the NOI Wetland Fee Transmittal Form) to confirm fee payment:

   2. Municipal Check Number
   3. Check date
   4. State Check Number
   5. Check date
   6. Payor name on check: First Name
   7. Payor name on check: Last Name
F. Signatures and Submittal Requirements

I hereby certify under the penalties of perjury that the foregoing Notice of Intent and accompanying plans, documents, and supporting data are true and complete to the best of my knowledge. I understand that the Conservation Commission will place notification of this Notice in a local newspaper at the expense of the applicant in accordance with the wetlands regulations, 310 CMR 10.05(5)(a).

I further certify under penalties of perjury that all abutters were notified of this application, pursuant to the requirements of M.G.L. c. 131, § 40. Notice must be made by Certificate of Mailing or in writing by hand delivery or certified mail (return receipt requested) to all abutters within 100 feet of the property line of the project location.

1. Signature of Applicant
01/29/14
2. Date

3. Signature of Property Owner (if different)
4. Date

5. Signature of Representative (if any)
6. Date

For Conservation Commission:
Two copies of the completed Notice of Intent (Form 3), including supporting plans and documents, two copies of the NOI Wetland Fee Transmittal Form, and the city/town fee payment, to the Conservation Commission by certified mail or hand delivery.

For MassDEP:
One copy of the completed Notice of Intent (Form 3), including supporting plans and documents, one copy of the NOI Wetland Fee Transmittal Form, and a copy of the state fee payment to the MassDEP Regional Office (see Instructions) by certified mail or hand delivery.

Other:
If the applicant has checked the “yes” box in any part of Section C, Item 3, above, refer to that section and the Instructions for additional submittal requirements.

The original and copies must be sent simultaneously. Failure by the applicant to send copies in a timely manner may result in dismissal of the Notice of Intent.
A. Applicant Information

1. Location of Project:
   - Lunenburg Road
   - Lancaster
     a. Street Address
     b. City/Town
     c. Check number
     d. Fee amount

2. Applicant Mailing Address:
   - Hannah Lee
     a. First Name
     b. Last Name
     c. WPI
     d. Organization
     e. 100 Institute Road
     f. Mailing Address
     g. Worcester
     h. City/Town
     i. MA
     j. State
     k. 01608
     l. Zip Code
     m. 508-579-2609
     n. Phone Number
     o. hlee15@wpi.edu
     p. Fax Number
     q. Email Address

3. Property Owner (if different):
   - Lancaster Conservation Commission
     a. First Name
     b. Last Name
     c. 695 Main St
     d. Mailing Address
     e. Lancaster
     f. City/Town
     g. MA
     h. State
     i. 01523
     j. Zip Code
     k. 978-365-3326
     l. Phone Number
     m. Fax Number
     n. Email Address

B. Fees

Fee should be calculated using the following process & worksheet. Please see Instructions before filling out worksheet.

Step 1/Type of Activity: Describe each type of activity that will occur in wetland resource area and buffer zone.

Step 2/Number of Activities: Identify the number of each type of activity.

Step 3/Individual Activity Fee: Identify each activity fee from the six project categories listed in the instructions.

Step 4/Subtotal Activity Fee: Multiply the number of activities (identified in Step 2) times the fee per category (identified in Step 3) to reach a subtotal fee amount. Note: If any of these activities are in a Riverfront Area in addition to another Resource Area or the Buffer Zone, the fee per activity should be multiplied by 1.5 and then added to the subtotal amount.

Step 5/Total Project Fee: Determine the total project fee by adding the subtotal amounts from Step 4.

Step 6/Fee Payments: To calculate the state share of the fee, divide the total fee in half and subtract $12.50. To calculate the city/town share of the fee, divide the total fee in half and add $12.50.
### B. Fees (continued)

<table>
<thead>
<tr>
<th>Step 1/Type of Activity</th>
<th>Step 2/Number of Activities</th>
<th>Step 3/Individual Activity Fee</th>
<th>Step 4/Subtotal Activity Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>$6291.80</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$6,291.80</td>
</tr>
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</tr>
</tbody>
</table>

**Step 5/Total Project Fee:**

**Step 6/Fee Payments:**

<table>
<thead>
<tr>
<th>Total Project Fee:</th>
<th>$6,291.80</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Total Fee from Step 5</td>
<td>$6,291.80</td>
</tr>
<tr>
<td>State share of filing Fee:</td>
<td>$3133.40</td>
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<tr>
<td>b. 1/2 Total Fee less $12.50</td>
<td>$3158.40</td>
</tr>
<tr>
<td>City/Town share of filing Fee:</td>
<td>$3158.40</td>
</tr>
<tr>
<td>c. 1/2 Total Fee plus $12.50</td>
<td>$3158.40</td>
</tr>
</tbody>
</table>

### C. Submittal Requirements

a.) Complete pages 1 and 2 and send with a check or money order for the state share of the fee, payable to the Commonwealth of Massachusetts.

Department of Environmental Protection
Box 4062
Boston, MA 02211

b.) **To the Conservation Commission:** Send the Notice of Intent or Abbreviated Notice of Intent; a **copy** of this form; and the city/town fee payment.

**To MassDEP Regional Office** (see Instructions): Send a copy of the Notice of Intent or Abbreviated Notice of Intent; a **copy** of this form; and a **copy** of the state fee payment. (E-filers of Notices of Intent may submit these electronically.)
Environmental Notification Form

For Office Use Only
EEA#: __________________________
MEPA Analyst: __________________

The information requested on this form must be completed in order to submit a document electronically for review under the Massachusetts Environmental Policy Act, 301 CMR 11.00.

Project Name: Improving Access to Nashua River-Bridge Construction
Street Address: Lunenburg Rd
Municipality: Lancaster Watershed: Nashua River
Universal Transverse Mercator Coordinates: Latitude: 42.5
Longitude: -71.69
Estimated commencement date: 2016 Estimated completion date: 2016
Project Type: Bridge Construction Status of project design: 70% complete
Proponent: Tom Christopher
Street Address: 252 Fort Pond Inn Road
Municipality: Lancaster State: MA Zip Code: 01523
Name of Contact Person: Hannah Lee
Firm/Agency: Worcester Polytechnic Institute Street Address: 100 Institute Road
Phone: 508-579-2609 Fax: E-mail: hlee15@wpi.edu

Does this project meet or exceed a mandatory EIR threshold (see 301 CMR 11.03)?
□ Yes ☑ No

If this is an Expanded Environmental Notification Form (ENF) (see 301 CMR 11.05(7)) or a Notice of Project Change (NPC), are you requesting:

a Single EIR? (see 301 CMR 11.06(8)) □ Yes ☑ No
a Special Review Procedure? (see 301CMR 11.09) ☑ Yes □ No
a Waiver of mandatory EIR? (see 301 CMR 11.11) ☑ Yes □ No
a Phase I Waiver? (see 301 CMR 11.11) ☑ Yes □ No
(Note: Greenhouse Gas Emissions analysis must be included in the Expanded ENF.)

Which MEPA review threshold(s) does the project meet or exceed (see 301 CMR 11.03)?
(11) ACEC
Which State Agency Permits will the project require? (MADEP) NOI

Identify any financial assistance or land transfer from an Agency of the Commonwealth, including the Agency name and the amount of funding or land area in acres:
<table>
<thead>
<tr>
<th>Summary of Project Size &amp; Environmental Impacts</th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LAND</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total site acreage</td>
<td>800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New acres of land altered</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Acres of impervious area</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Square feet of new bordering vegetated wetlands alteration</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Square feet of new other wetland alteration</td>
<td>600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acres of new non-water dependent use of tidelands or waterways</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td><strong>STRUCTURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross square footage</td>
<td>200</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>Number of housing units</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum height (feet)</td>
<td></td>
<td>Railings 4 ft</td>
<td></td>
</tr>
<tr>
<td><strong>TRANSPORTATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle trips per day</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Parking spaces</td>
<td>3 acres</td>
<td>3 acres</td>
<td>3 acres</td>
</tr>
<tr>
<td><strong>WASTEWATER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Use (Gallons per day)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Water withdrawal (GPD)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wastewater generation/treatment (GPD)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Length of water mains (miles)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Length of sewer mains (miles)</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Has this project been filed with MEPA before?</td>
<td></td>
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<tr>
<td>☐ Yes (EEA #__________) ☑ No</td>
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<tr>
<td>Has any project on this site been filed with MEPA before?</td>
<td></td>
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<tr>
<td>☐ Yes (EEA #__________) ☑ No</td>
<td></td>
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</tr>
</tbody>
</table>
GENERAL PROJECT INFORMATION – all proponents must fill out this section

PROJECT DESCRIPTION:
Describe the existing conditions and land uses on the project site: **Conservation area with trails for visitors**
Describe the proposed project and its programmatic and physical elements: **Bridge building to improve trails**

**NOTE:** The project description should summarize both the project’s direct and indirect impacts (including construction period impacts) in terms of their magnitude, geographic extent, duration and frequency, and reversibility, as applicable. It should also discuss the infrastructure requirements of the project and the capacity of the municipal and/or regional infrastructure to sustain these requirements into the future.

Describe the on-site project alternatives (and alternative off-site locations, if applicable), considered by the proponent, including at least one feasible alternative that is allowed under current zoning, and the reasons(s) that they were not selected as the preferred alternative:

- **No other alternative**

**NOTE:** The purpose of the alternatives analysis is to consider what effect changing the parameters and/or siting of a project, or components thereof, will have on the environment, keeping in mind that the objective of the MEPA review process is to avoid or minimize damage to the environment to the greatest extent feasible. Examples of alternative projects include alternative site locations, alternative site uses, and alternative site configurations.

Summarize the mitigation measures proposed to offset the impacts of the preferred alternative:
- **No other alternative**

If the project is proposed to be constructed in phases, please describe each phase:

**AREAS OF CRITICAL ENVIRONMENTAL CONCERN:**
Is the project within or adjacent to an Area of Critical Environmental Concern?

- **Yes** (Specify **Central Nashua Valley**)
- **No**

If yes, does the ACEC have an approved Resource Management Plan? ___ Yes ___ No;
If yes, describe how the project complies with this plan.

Will there be stormwater runoff or discharge to the designated ACEC? ___ Yes ___ No;
If yes, describe and assess the potential impacts of such stormwater runoff/discharge to the designated ACEC.

**RARE SPECIES:**
Does the project site include Estimated and/or Priority Habitat of State-Listed Rare Species? (see [http://www.mass.gov/dpwm/dfw/nhsp/regulatory_review/priority_habitat/priority_habitat_home.htm](http://www.mass.gov/dpwm/dfw/nhsp/regulatory_review/priority_habitat/priority_habitat_home.htm))

- **Yes** (Specify **BAH-2 Central Habitat**)
- **No**

**HISTORICAL / ARCHAEOLOGICAL RESOURCES:**
Does the project site include any structure, site or district listed in the State Register of Historic Place or the inventory of Historic and Archaeological Assets of the Commonwealth?

- **Yes** (Specify _____________________________)
- **No**

If yes, does the project involve any demolition or destruction of any listed or inventoried historic or archaeological resources? ___ Yes (Specify_______________________________) ___ No
WATER RESOURCES:
Is there an Outstanding Resource Water (ORW) on or within a half-mile radius of the project site? Yes ☑️ No; if yes, identify the ORW and its location.

(NOTE: Outstanding Resource Waters include Class A public water supplies, their tributaries, and bordering wetlands; active and inactive reservoirs approved by MassDEP; certain waters within Areas of Critical Environmental Concern, and certified vernal pools. Outstanding resource waters are listed in the Surface Water Quality Standards, 314 CMR 4.00.)

Are there any impaired water bodies on or within a half-mile radius of the project site? Yes ☑️ No; if yes, identify the water body and pollutant(s) causing the impairment: Nashua River-Urban Runoff.

Is the project within a medium or high stress basin, as established by the Massachusetts Water Resources Commission? Yes ☑️ No

STORMWATER MANAGEMENT:
Generally describe the project’s stormwater impacts and measures that the project will take to comply with the standards found in MassDEP’s Stormwater Management Regulations: Not Applicable

MASSACHUSETTS CONTINGENCY PLAN:
Has the project site been, or is it currently being, regulated under M.G.L.c.21E or the Massachusetts Contingency Plan? site (including Release Tracking Number (RTN), cleanup phase, and Response Action Outcome classification): No

Is there an Activity and Use Limitation (AUL) on any portion of the project site? Yes ☑️ No; if yes, describe which portion of the site and how the project will be consistent with the AUL.

Are you aware of any Reportable Conditions at the property that have not yet been assigned an RTN? Yes ☑️ No ☑️; if yes, please describe:

SOLID AND HAZARDOUS WASTE:
If the project will generate solid waste during demolition or construction, describe alternatives considered for re-use, recycling, and disposal of, e.g., asphalt, brick, concrete, gypsum, metal, wood: No

(NOTE: Asphalt pavement, brick, concrete and metal are banned from disposal at Massachusetts landfills and waste combustion facilities and wood is banned from disposal at Massachusetts landfills. See 310 CMR 19.017 for the complete list of banned materials.)

Will your project disturb asbestos containing materials? Yes ☑️ No ☑️; if yes, please consult state asbestos requirements at http://mass.gov/MassDEP/air/asbhom01.htm

Describe anti-idling and other measures to limit emissions from construction equipment: Equipment Shutdown during Non-use

DESIGNATED WILD AND SCENIC RIVER:
Is this project site located wholly or partially within a defined river corridor of a federally designated Wild and Scenic River or a state designated Scenic River? Yes ☑️ No ☑️; if yes, specify name of river and designation:

If yes, does the project have the potential to impact any of the “outstandingly remarkable” resources of a federally Wild and Scenic River or the stated purpose of a state designated Scenic River? Yes ☑️ No ☑️; if yes, specify name of river and designation:

If yes, will the project result in any impacts to any of the designated “outstandingly remarkable” resources of the Wild and Scenic River or the stated purposes of a Scenic River. Yes ☑️ No ☑️; if yes, describe the potential impacts to one or more of the “outstandingly remarkable” resources or stated purposes and mitigation measures proposed.
ATTACHMENTS:

1. List of all attachments to this document.
2. U.S.G.S. map (good quality color copy, 8-½ x 11 inches or larger, at a scale of 1:24,000) indicating the project location and boundaries.
3. Plan, at an appropriate scale, of existing conditions on the project site and its immediate environs, showing all known structures, roadways and parking lots, railroad rights-of-way, wetlands and water bodies, wooded areas, farmland, steep slopes, public open spaces, and major utilities.
4. Plan, at an appropriate scale, depicting environmental constraints on or adjacent to the project site such as Priority and/or Estimated Habitat of state-listed rare species, Areas of Critical Environmental Concern, Chapter 91 jurisdictional areas, Article 97 lands, wetland resource area delineations, water supply protection areas, and historic resources and/or districts.
5. Plan, at an appropriate scale, of proposed conditions upon completion of project (if construction of the project is proposed to be phased, there should be a site plan showing conditions upon the completion of each phase).
6. List of all agencies and persons to whom the proponent circulated the ENF, in accordance with 301 CMR 11.16(2).
7. List of municipal and federal permits and reviews required by the project, as applicable.
LAND SECTION – all proponents must fill out this section

I. Thresholds / Permits
   A. Does the project meet or exceed any review thresholds related to land (see 301 CMR 11.03(1))
      _ _ _ Yes _ _ _ No; if yes, specify each threshold:

II. Impacts and Permits
   A. Describe, in acres, the current and proposed character of the project site, as follows:

       | Existing | Change | Total |
       |----------|--------|-------|
       | Footprint of buildings        |        |       |
       | Internal roadways             |        |       |
       | Parking and other paved areas |        |       |
       | Other altered areas           |        |       |
       | Undeveloped areas             |        |       |
       | Total: Project Site Acreage   | 4.5 acres | 1.5 acres |

   B. Has any part of the project site been in active agricultural use in the last five years?
      _ _ _ Yes _ _ _ No; if yes, how many acres of land in agricultural use (with prime state or
      locally important agricultural soils) will be converted to nonagricultural use?

   C. Is any part of the project currently or proposed to be in active forestry use?
      _ _ _ Yes _ _ _ No; if yes, please describe current and proposed forestry activities and
      indicate whether any part of the site is the subject of a forest management plan approved by
      the Department of Conservation and Recreation:

   D. Does any part of the project involve conversion of land held for natural resources purposes in
      accordance with Article 97 of the Amendments to the Constitution of the Commonwealth to
      any purpose not in accordance with Article 97? _ _ _ Yes _ _ _ No; if yes, describe:

   E. Is any part of the project site currently subject to a conservation restriction, preservation
      restriction, agricultural preservation restriction or watershed preservation restriction? _ _ _ Yes _ _ _ No; if yes, does the project involve the release or modification of such restriction?
      _ _ _ Yes _ _ _ No; if yes, describe:

   F. Does the project require approval of a new urban redevelopment project or a fundamental change
      in an existing urban redevelopment project under M.G.L.c.121A? _ _ _ Yes _ _ _ No; if yes, describe:

   G. Does the project require approval of a new urban renewal plan or a major modification of an
      existing urban renewal plan under M.G.L.c.121B? Yes _ _ _ No _ _ _ ; if yes, describe:

III. Consistency
   A. Identify the current municipal comprehensive land use plan
      Title: Cook Conservation Area Date 2010

   B. Describe the project’s consistency with that plan with regard to:
      1) economic development _ _ _ None
      2) adequacy of infrastructure _ _ _ None
      3) open space impacts _ _ _ Yes
      4) compatibility with adjacent land uses _ _ _ None

   C. Identify the current Regional Policy Plan of the applicable Regional Planning Agency (RPA)
      RPA: Massachusetts Regional Planning/Conservation and Trails
D. Describe the project's consistency with that plan with regard to:
   1) economic development
   2) adequacy of infrastructure
   3) open space impacts _Protection of existing open space_
RARE SPECIES SECTION

I. Thresholds / Permits
A. Will the project meet or exceed any review thresholds related to rare species or habitat (see 301 CMR 11.03(2))? □ Yes □ No; if yes, specify, in quantitative terms:

(Note: If you are uncertain, it is recommended that you consult with the Natural Heritage and Endangered Species Program (NHESP) prior to submitting the ENF.)

B. Does the project require any state permits related to rare species or habitat? □ Yes □ No

C. Does the project site fall within mapped rare species habitat (Priority or Estimated Habitat?) in the current Massachusetts Natural Heritage Atlas (attach relevant page)? □ Yes □ No.

D. If you answered "No" to all questions A, B and C, proceed to the Wetlands, Waterways, and Tidelands Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Rare Species section below.

II. Impacts and Permits
A. Does the project site fall within Priority or Estimated Habitat in the current Massachusetts Natural Heritage Atlas (attach relevant page)? □ Yes □ No. If yes, 1. Have you consulted with the Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program (NHESP)? □ Yes □ No; if yes, have you received a determination as to whether the project will result in the "take" of a rare species? □ Yes □ No; if yes, attach the letter of determination to this submission.

2. Will the project "take" an endangered, threatened, and/or species of special concern in accordance with M.G.L. c.131A (see also 321 CMR 10.04)? □ Yes □ No; if yes, provide a summary of proposed measures to minimize and mitigate rare species impacts.

3. Which rare species are known to occur within the Priority or Estimated Habitat?
   Unknown

4. Has the site been surveyed for rare species in accordance with the Massachusetts Endangered Species Act? □ Yes □ No

4. If your project is within Estimated Habitat, have you filed a Notice of Intent or received an Order of Conditions for this project? □ Yes □ No; if yes, did you send a copy of the Notice of Intent to the Natural Heritage and Endangered Species Program, in accordance with the Wetlands Protection Act regulations? □ Yes □ No

B. Will the project "take" an endangered, threatened, and/or species of special concern in accordance with M.G.L. c.131A (see also 321 CMR 10.04)? □ Yes □ No; if yes, provide a summary of proposed measures to minimize and mitigate impacts to significant habitat:
**WETLANDS, WATERWAYS, AND TIDELANDS SECTION**

I. **Thresholds / Permits**
   A. Will the project meet or exceed any review thresholds related to wetlands, waterways, and tidelands (see 301 CMR 11.03(3))? ___ Yes ___ No; if yes, specify, in quantitative terms:

   B. Does the project require any state permits (or a local Order of Conditions) related to wetlands, waterways, or tidelands? ___ Yes ___ No; if yes, specify which permit: **WPA-3, Notice of Intent**

   C. If you answered "No" to both questions A and B, proceed to the Water Supply Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Wetlands, Waterways, and Tideland Section below.

II. **Wetlands Impacts and Permits**
   A. Does the project require a new or amended Order of Conditions under the Wetlands Protection Act (M.G.L. c.131A)? ___ Yes ___ No; if yes, has a Notice of Intent been filed? ___ Yes ___ No; if yes, list the date and MassDEP file number: ; if yes, has a local Order of Conditions been issued? ___ Yes ___ No; Was the Order of Conditions appealed? ___ Yes ___ No. Will the project require a Variance from the Wetlands regulations? ___ Yes ___ No.

   B. Describe any proposed permanent or temporary impacts to wetland resource areas located on the project site:

   **Bank disturbed - linear feet**

   C. Estimate the extent and type of impact that the project will have on wetland resources, and indicate whether the impacts are temporary or permanent:

<table>
<thead>
<tr>
<th>Coastal Wetlands</th>
<th>Area (square feet) or Length (linear feet)</th>
<th>Temporary or Permanent Impact?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Under the Ocean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designated Port Areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal Beaches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal Dunes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrier Beaches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal Banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocky Intertidal Shores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt Marshes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Under Salt Ponds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Containing Shellfish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish Runs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Subject to Coastal Storm Flowage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   | Inland Wetlands                        |                                            |                                |
   | Bank (if)                              |                                            |                                |
   | Bordering Vegetated Wetlands           |                                            |                                |
   | Isolated Vegetated Wetlands            |                                            |                                |
   | Land Under Water                       |                                            |                                |
   | Isolated Land Subject to Flooding      |                                            |                                |
   | Bordering Land Subject to Flooding    |                                            |                                |
   | Riverfront Area                        | 200                                        | 200                            |

   D. Is any part of the project:
   1. proposed as a limited project? ___ Yes ___ No; if yes, what is the area (in sf)? ___
   2. the construction or alteration of a dam? ___ Yes ___ No; if yes, describe:
   3. fill or structure in a velocity zone or regulatory floodway? ___ Yes ___ No
   4. dredging or disposal of dredged material? ___ Yes ___ No; if yes, describe the volume
of dredged material and the proposed disposal site:
5. a discharge to an Outstanding Resource Water (ORW) or an Area of Critical Environmental Concern (ACEC)? Yes No
6. subject to a wetlands restriction order? Yes No; if yes, identify the area (in sf):
7. located in buffer zones? Yes No; if yes, how much (in sf) 200 sq. ft

E. Will the project:
1. be subject to a local wetlands ordinance or bylaw? Yes No
2. alter any federally-protected wetlands not regulated under state law? Yes No; if yes, what is the area (sf)?

III. Waterways and Tidelands Impacts and Permits
A. Does the project site contain waterways or tidelands (including filled former tidelands) that are subject to the Waterways Act, M.G.L.c.91? Yes No; if yes, is there a current Chapter 91 License or Permit affecting the project site? Yes No; if yes, list the date and license or permit number and provide a copy of the historic map used to determine extent of filled tidelands:
B. Does the project require a new or modified license or permit under M.G.L.c.91? Yes No; if yes, how many acres of the project site subject to M.G.L.c.91 will be for non-water-dependent use? Current Change Total
If yes, how many square feet of solid fill or pile-supported structures (in sf)?
C. For non-water-dependent use projects, indicate the following:
Area of filled tidelands on the site: 0
Area of filled tidelands covered by buildings: 0
For portions of site on filled tidelands, list ground floor uses and area of each use:
Does the project include new non-water-dependent uses located over flowed tidelands? Yes No
Height of building on filled tidelands N/A
Also show the following on a site plan: Mean High Water, Mean Low Water, Water-dependent Use Zone, location of uses within buildings on tidelands, and interior and exterior areas and facilities dedicated for public use, and historic high and historic low water marks.
D. Is the project located on landlocked tidelands? Yes No; if yes, describe the project's impact on the public's right to access, use and enjoy jurisdictional tidelands and describe measures the project will implement to avoid, minimize or mitigate any adverse impact:
E. Is the project located in an area where low groundwater levels have been identified by a municipality or by a state or federal agency as a threat to building foundations? Yes No; if yes, describe the project's impact on groundwater levels and describe measures the project will implement to avoid, minimize or mitigate any adverse impact:
F. Is the project non-water-dependent and located on landlocked tidelands or waterways or tidelands subject to the Waterways Act and subject to a mandatory EIR? Yes No
(NOTE: If yes, then the project will be subject to Public Benefit Review and Determination.)
G. Does the project include dredging? Yes No; if yes, answer the following questions:
What type of dredging? Improvement Maintenance Both
What is the proposed dredge volume, in cubic yards (cys) 0
What is the proposed dredge footprint \( \text{N/A} \) length (ft) \( \text{N/A} \) width (ft) \( \text{N/A} \) depth (ft);

Will dredging impact the following resource areas?

- Intertidal: Yes \( \text{N/A} \) No; if yes, ___ sq ft
- Outstanding Resource Waters: Yes \( \text{N/A} \) No; if yes, ___ sq ft
- Other resource area (i.e. shellfish beds, eel grass beds): Yes \( \text{N/A} \) No; if yes ___ sq ft

If yes to any of the above, have you evaluated appropriate and practicable steps to: 1) avoidance; 2) if avoidance is not possible, minimization; 3) if either avoidance or minimize is not possible, mitigation?

If no to any of the above, what information or documentation was used to support this determination?

Provide a comprehensive analysis of practicable alternatives for improvement dredging in accordance with 314 CMR 9.07(1)(b). Physical and chemical data of the sediment shall be included in the comprehensive analysis.

**Sediment Characterization**

- Existing gradation analysis results? \( \text{N/A} \) Yes \( \checkmark \) No; if yes, provide results.
- Existing chemical results for parameters listed in 314 CMR 9.07(2)(b)? \( \text{N/A} \) Yes \( \checkmark \) No; if yes, provide results.

Do you have sufficient information to evaluate feasibility of the following management options for dredged sediment? If yes, check the appropriate option.

- Beach Nourishment \( \text{N/A} \)
- Unconfined Ocean Disposal \( \text{N/A} \)
- Confined Disposal:
  - Confined Aquatic Disposal (CAD) \( \text{N/A} \)
  - Confined Disposal Facility (CDF) \( \text{N/A} \)
- Landfill Reuse in accordance with COMM-97-001 \( \text{N/A} \)
- Shoreline Placement \( \text{N/A} \)
- Upland Material Reuse \( \text{N/A} \)
- In-State landfill disposal \( \text{N/A} \)
- Out-of-state landfill disposal \( \text{N/A} \)

*(NOTE: This information is required for a 401 Water Quality Certification.)*

**IV. Consistency:**

A. Does the project have effects on the coastal resources or uses, and/or is the project located within the Coastal Zone? \( \text{N/A} \) Yes \( \checkmark \) No; if yes, describe these effects and the projects consistency with the policies of the Office of Coastal Zone Management:

B. Is the project located within an area subject to a Municipal Harbor Plan? \( \text{N/A} \) Yes \( \checkmark \) No; if yes, identify the Municipal Harbor Plan and describe the project’s consistency with that plan:
WATER SUPPLY SECTION

I. Thresholds / Permits
   A. Will the project meet or exceed any review thresholds related to water supply (see 301 CMR 11.03(4))? ___ Yes ☑ No; if yes, specify, in quantitative terms:

   B. Does the project require any state permits related to water supply? ___ Yes ☑ No; if yes, specify which permit:

   C. If you answered "No" to both questions A and B, proceed to the Wastewater Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Water Supply Section below.

II. Impacts and Permits
   A. Describe, in gallons per day (gpd), the volume and source of water use for existing and proposed activities at the project site:

<table>
<thead>
<tr>
<th>Source</th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal or regional water supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdrawal from groundwater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdrawal from surface water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interbasin transfer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   (NOTE: Interbasin Transfer approval will be required if the basin and community where the proposed water supply source is located is different from the basin and community where the wastewater from the source will be discharged.)

   B. If the source is a municipal or regional supply, has the municipality or region indicated that there is adequate capacity in the system to accommodate the project? ___ Yes ___ No

   C. If the project involves a new or expanded withdrawal from a groundwater or surface water source, has a pumping test been conducted? ___ Yes ___ No; if yes, attach a map of the drilling sites and a summary of the alternatives considered and the results.

   D. What is the currently permitted withdrawal at the proposed water supply source (in gallons per day)? ___Will the project require an increase in that withdrawal? ___Yes ___No; if yes, then how much of an increase (gpd)?

   E. Does the project site currently contain a water supply well, a drinking water treatment facility, water main, or other water supply facility, or will the project involve construction of a new facility? ___ Yes ___ No. If yes, describe existing and proposed water supply facilities at the project site:

<table>
<thead>
<tr>
<th>Facility</th>
<th>Permitted Flow</th>
<th>Existing Avg Daily Flow</th>
<th>Project Flow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity of water supply well(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity of water treatment plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   F. If the project involves a new interbasin transfer of water, which basins are involved, what is the direction of the transfer, and is the interbasin transfer existing or proposed?

   G. Does the project involve:
      1. new water service by the Massachusetts Water Resources Authority or other agency of the Commonwealth to a municipality or water district? ___Yes ___ No
      2. a Watershed Protection Act variance? ___ Yes ___ No; if yes, how many acres of alteration?
      3. a non-bridged stream crossing 1,000 or less feet upstream of a public surface drinking water supply for purpose of forest harvesting activities? ___ Yes ___ No
III. Consistency

Describe the project's consistency with water conservation plans or other plans to enhance water resources, quality, facilities and services:
WASTEWATER SECTION

I. Thresholds / Permits
A. Will the project meet or exceed any review thresholds related to wastewater (see 301 CMR 11.03(5))?  ___ Yes ✓ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to wastewater?  ___ Yes ✓ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Transportation -- Traffic Generation Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Wastewater Section below.

II. Impacts and Permits
A. Describe the volume (in gallons per day) and type of disposal of wastewater generation for existing and proposed activities at the project site (calculate according to 310 CMR 15.00 for septic systems or 314 CMR 7.00 for sewer systems):

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge of sanitary wastewater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge of industrial wastewater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge to groundwater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge to outstanding resource water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge to surface water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge to municipal or regional wastewater facility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Is the existing collection system at or near its capacity?  ___ Yes ___ No; if yes, then describe the measures to be undertaken to accommodate the project’s wastewater flows:

C. Is the existing wastewater disposal facility at or near its permitted capacity?  ___ Yes ___ No; if yes, then describe the measures to be undertaken to accommodate the project’s wastewater flows:

D. Does the project site currently contain a wastewater treatment facility, sewer main, or other wastewater disposal facility, or will the project involve construction of a new facility?  ___ Yes ___ No; if yes, describe as follows:

<table>
<thead>
<tr>
<th></th>
<th>Permitted</th>
<th>Existing Avg Daily Flow</th>
<th>Project Flow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater treatment plant capacity (in gallons per day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

E. If the project requires an interbasin transfer of wastewater, which basins are involved, what is the direction of the transfer, and is the interbasin transfer existing or new?

(NOTE: Interbasin Transfer approval may be needed if the basin and community where wastewater will be discharged is different from the basin and community where the source of water supply is
located.)

F. Does the project involve new sewer service by the Massachusetts Water Resources Authority (MWRA) or other Agency of the Commonwealth to a municipality or sewer district? ___ Yes ___ No

G. Is there an existing facility, or is a new facility proposed at the project site for the storage, treatment, processing, combustion or disposal of sewage sludge, sludge ash, grit, screenings, wastewater reuse (gray water) or other sewage residual materials? ___ Yes ___ No; if yes, what is the capacity (tons per day):

<table>
<thead>
<tr>
<th>Storage</th>
<th>Treatment</th>
<th>Processing</th>
<th>Combustion</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>Change</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

H. Describe the water conservation measures to be undertaken by the project, and other wastewater mitigation, such as infiltration and inflow removal.

III. Consistency
A. Describe measures that the proponent will take to comply with applicable state, regional, and local plans and policies related to wastewater management:

B. If the project requires a sewer extension permit, is that extension included in a comprehensive wastewater management plan? ___ Yes ___ No; if yes, indicate the EEA number for the plan and whether the project site is within a sewer service area recommended or approved in that plan:
TRANSPORTATION SECTION (TRAFFIC GENERATION)

I. Thresholds / Permit
   A. Will the project meet or exceed any review thresholds related to traffic generation (see 301 CMR 11.03(6))? ___ Yes ☑ No; if yes, specify, in quantitative terms:

   B. Does the project require any state permits related to state-controlled roadways? ___ Yes ☑ No; if yes, specify which permit:

   C. If you answered "No" to both questions A and B, proceed to the Roadways and Other Transportation Facilities Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Traffic Generation Section below.

II. Traffic Impacts and Permits
   A. Describe existing and proposed vehicular traffic generated by activities at the project site:

<table>
<thead>
<tr>
<th>Number of parking spaces</th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicle trips per day</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   | ITE Land Use Code(s): |          |        |       |

   B. What is the estimated average daily traffic on roadways serving the site?

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
</table>

C. If applicable, describe proposed mitigation measures on state-controlled roadways that the project proponent will implement:

D. How will the project implement and/or promote the use of transit, pedestrian and bicycle facilities and services to provide access to and from the project site?

E. Is there a Transportation Management Association (TMA) that provides transportation demand management (TDM) services in the area of the project site? ____ Yes ____ No; if yes, describe if and how will the project will participate in the TMA:

F. Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation facilities? ____ Yes ____ No; if yes, generally describe:

G. If the project will penetrate approach airspace of a nearby airport, has the proponent filed a Massachusetts Aeronautics Commission Airspace Review Form (780 CMR 111.7) and a Notice of Proposed Construction or Alteration with the Federal Aviation Administration (FAA) (CFR Title 14 Part 77.13, forms 7460-1 and 7460-2)?

III. Consistency
   Describe measures that the proponent will take to comply with municipal, regional, state, and federal plans and policies related to traffic, transit, pedestrian and bicycle transportation facilities and services:
TRANSPORTATION SECTION (ROADWAYS AND OTHER TRANSPORTATION FACILITIES)

I. Thresholds
   A. Will the project meet or exceed any review thresholds related to roadways or other transportation facilities (see 301 CMR 11.03(6))? ___ Yes  No; if yes, specify, in quantitative terms:

   B. Does the project require any state permits related to roadways or other transportation facilities? ___ Yes  No; if yes, specify which permit:

   C. If you answered "No" to both questions A and B, proceed to the Energy Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Roadways Section below.

II. Transportation Facility Impacts
   A. Describe existing and proposed transportation facilities in the immediate vicinity of the project site:

   B. Will the project involve any
      1. Alteration of bank or terrain (in linear feet)?
      2. Cutting of living public shade trees (number)?
      3. Elimination of stone wall (in linear feet)?

III. Consistency -- Describe the project's consistency with other federal, state, regional, and local plans and policies related to traffic, transit, pedestrian and bicycle transportation facilities and services, including consistency with the applicable regional transportation plan and the Transportation Improvements Plan (TIP), the State Bicycle Plan, and the State Pedestrian Plan:
ENERGY SECTION

I. Thresholds / Permits
   A. Will the project meet or exceed any review thresholds related to energy (see 301 CMR 11.03(7))? ___ Yes ✓ No; if yes, specify, in quantitative terms:

   B. Does the project require any state permits related to energy? ___ Yes ✓ No; if yes, specify which permit:

   C. If you answered "No" to both questions A and B, proceed to the Air Quality Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Energy Section below.

II. Impacts and Permits
   A. Describe existing and proposed energy generation and transmission facilities at the project site:

<table>
<thead>
<tr>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity of electric generating facility (megawatts)</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Length of fuel line (in miles)</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Length of transmission lines (in miles)</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>Capacity of transmission lines (in kilovolts)</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

   B. If the project involves construction or expansion of an electric generating facility, what are:
      1. the facility's current and proposed fuel source(s)?
      2. the facility's current and proposed cooling source(s)?

   C. If the project involves construction of an electrical transmission line, will it be located on a new, unused, or abandoned right of way? ___Yes ___No; if yes, please describe:

   D. Describe the project's other impacts on energy facilities and services:

III. Consistency
   Describe the project's consistency with state, municipal, regional, and federal plans and policies for enhancing energy facilities and services:
AIR QUALITY SECTION

I. Thresholds
   A. Will the project meet or exceed any review thresholds related to air quality (see 301 CMR 11.03(8))? ___ Yes ☑ No; if yes, specify, in quantitative terms:

   B. Does the project require any state permits related to air quality? ___ Yes ☑ No; if yes, specify which permit:

   C. If you answered "No" to both questions A and B, proceed to the Solid and Hazardous Waste Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Air Quality Section below.

II. Impacts and Permits
   A. Does the project involve construction or modification of a major stationary source (see 310 CMR 7.00, Appendix A)? ___ Yes ___ No; if yes, describe existing and proposed emissions (in tons per day) of:

<table>
<thead>
<tr>
<th>Particulate matter</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Volatile organic compounds</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Oxides of nitrogen</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Lead</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Any hazardous air pollutant</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>

   B. Describe the project's other impacts on air resources and air quality, including noise impacts:

III. Consistency
   A. Describe the project's consistency with the State Implementation Plan:

   B. Describe measures that the proponent will take to comply with other federal, state, regional, and local plans and policies related to air resources and air quality:
SOLID AND HAZARDOUS WASTE SECTION

I. Thresholds / Permits
A. Will the project meet or exceed any review thresholds related to solid or hazardous waste (see 301 CMR 11.03(9))? ___ Yes ☑ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to solid and hazardous waste? ___ Yes ☑ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Historical and Archaeological Resources Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Solid and Hazardous Waste Section below.

II. Impacts and Permits
A. Is there any current or proposed facility at the project site for the storage, treatment, processing, combustion or disposal of solid waste? ___ Yes ___ No; if yes, what is the volume (in tons per day) of the capacity:

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Treatment, processing</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Combustion</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Disposal</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>

B. Is there any current or proposed facility at the project site for the storage, recycling, treatment or disposal of hazardous waste? ___ Yes ___ No; if yes, what is the volume (in tons or gallons per day) of the capacity:

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Change</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Recycling</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Treatment</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Disposal</td>
<td>________</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>

C. If the project will generate solid waste (for example, during demolition or construction), describe alternatives considered for re-use, recycling, and disposal:

D. If the project involves demolition, do any buildings to be demolished contain asbestos? ___ Yes ___ No

E. Describe the project's other solid and hazardous waste impacts (including indirect impacts):

III. Consistency
Describe measures that the proponent will take to comply with the State Solid Waste Master Plan:
HISTORICAL AND ARCHAEOLOGICAL RESOURCES SECTION

I. Thresholds / Impacts
   A. Have you consulted with the Massachusetts Historical Commission? ___ Yes Yes No; if yes, attach correspondence. For project sites involving lands under water, have you consulted with the Massachusetts Board of Underwater Archaeological Resources? ____Yes __ No; if yes, attach correspondence

   B. Is any part of the project site a historic structure, or a structure within a historic district, in either case listed in the State Register of Historic Places or the Inventory of Historic and Archaeological Assets of the Commonwealth? ___ Yes Yes No; if yes, does the project involve the demolition of all or any exterior part of such historic structure? ____Yes ___ No; if yes, please describe:

   C. Is any part of the project site an archaeological site listed in the State Register of Historic Places or the Inventory of Historic and Archaeological Assets of the Commonwealth? ____Yes Yes No; if yes, does the project involve the destruction of all or any part of such archaeological site? ____Yes ___ No; if yes, please describe:

   D. If you answered "No" to all parts of both questions A, B and C, proceed to the Attachments and Certifications Sections. If you answered "Yes" to any part of either question A or question B, fill out the remainder of the Historical and Archaeological Resources Section below.

II. Impacts
   Describe and assess the project's impacts, direct and indirect, on listed or inventoried historical and archaeological resources:

III. Consistency
   Describe measures that the proponent will take to comply with federal, state, regional, and local plans and policies related to preserving historical and archaeological resources:
CERTIFICATIONS:

1. The Public Notice of Environmental Review has been/will be published in the following newspapers in accordance with 301 CMR 11.15(1):

   (Name) **Pending**                     (Date)   **Pending**

2. This form has been circulated to Agencies and Persons in accordance with 301 CMR 11.16(2).

Signatures:

<table>
<thead>
<tr>
<th>Date</th>
<th>Signature of Responsible Officer or Proponent</th>
<th>Date</th>
<th>Signature of person preparing NPC (if different from above)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Name (print or type)                                               Name (print or type)
Firm/Agency                                                     Firm/Agency
Street                                                          Street
Municipality/State/Zip                                          Municipality/State/Zip
Phone                                                           Phone
Appendix F- Cost Estimation

<table>
<thead>
<tr>
<th>Bridge Materials</th>
<th>Unit Price</th>
<th>Quantity Needed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; Galvanized Lag Bolts</td>
<td>$13.02</td>
<td>8</td>
<td>$104.16</td>
</tr>
<tr>
<td>4&quot; x 16&quot; P.T. Lumber</td>
<td>$11.17</td>
<td>65</td>
<td>$726.05</td>
</tr>
<tr>
<td>4&quot; x 4&quot; P. T Lumber</td>
<td>$8.17</td>
<td>4</td>
<td>$32.68</td>
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<tr>
<td>2&quot; x 4&quot; P.T Lumber</td>
<td>$3.97</td>
<td>60</td>
<td>$238.20</td>
</tr>
<tr>
<td>3/4&quot; Galvanized Timber Bolts</td>
<td>$9.39</td>
<td>24</td>
<td>$225.36</td>
</tr>
<tr>
<td>125' Architectural Steel Cable</td>
<td>$59.77</td>
<td>1</td>
<td>$59.77</td>
</tr>
<tr>
<td>2&quot; x 6&quot; P.T Lumber for decking</td>
<td>$5.17</td>
<td>101</td>
<td>$522.17</td>
</tr>
<tr>
<td>18&quot; diameter Sonotube</td>
<td>$10.20</td>
<td>4</td>
<td>$40.80</td>
</tr>
<tr>
<td>1000 galvanized screws</td>
<td>$46.71</td>
<td>1</td>
<td>$46.71</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$1,995.90</strong></td>
</tr>
</tbody>
</table>

Figure 27: Cost of materials estimate for one bridge

<table>
<thead>
<tr>
<th>Materials</th>
<th>Transportation</th>
<th>Human Labor</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,995.90</td>
<td>$350.00</td>
<td>$500.00</td>
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<tr>
<td>$1,995.90</td>
<td>$500.00</td>
<td>$650.00</td>
<td>$200.00</td>
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<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td></td>
<td><strong>$6,291.80</strong></td>
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</tbody>
</table>

Figure 28: Cost estimate for both bridges combined, including transportation, labor, and maintenance costs
Appendix G- Maps

Appendix G1- GIS Map

Figure 29: GIS soils map of the Cook Conservation Area, used to confirm the results of our soils testing
Figure 30: 2D topographic map created by the team of the Farnsworth – 0.5 Mi. site

Figure 31: Three dimensional topographic map created by the team of the Farnsworth – 0.5 Mi. site
Appendix G3- USGS Map

Figure 32: USGS map of the Cook Conservation Area showing the precise locations of each bridge site
Appendix G4- Buffer Zone Map

Figure 33: Buffer zone map used to show which protection specifications will apply to construction
Improving Public Access to the Nashua River in Lancaster, MA - Phase II
Site Visit Report

SITE VISIT NO. 01

Date: 4 September 2014
Time: 5:30 p.m. to 6:00 p.m.
Location: Cook’s Conservation Land, Lancaster, MA
Report By: JP Connors
Project Team Members in Attendance: Adam Carrier, JP Connors, Hannah Lee, Jeremy Soderholm

1. PURPOSE
Tom Christopher of the Lancaster Friends of the Nashua River met our IQP group to conduct an initial visit at the Cook Conservation Area. Mr. Christopher presented us with two project opportunities described below and spoke generally about the land and the importance of our work.

2. PERSONS CONTACTED
Thomas J. Christopher, Lancaster Friends of the Nashua River
David I. Spanagal, Worcester Polytechnic Institute

3. GENERAL OBSERVATIONS
- The Cook Conservation Area is located on Lunenburg Road approximately 1.5 miles north of the intersection of Routes 117 & 70 in Lancaster, MA.
- Parking on-site is limited to a small dirt parking lot that can accommodate approximately 5 vehicles.
- The conservation area is a microcosm of New England and varies widely in terrain and habitats.
4. PROJECT 1

- Design an ADA compliant access route and ramp to a river front grove located approximately 1000 ft. from the entrance to the Cook Conservation area.
- Design a picnic area on the river front consisting of approximately 6 picnic tables anchored to the floodplain.
- Develop a plan to construct this handicap accessible picnic area and include a cost analysis, materials list, and conduct the necessary work to obtain a project permit from the town of Lancaster.
- Ensure design takes into account endangered species, Army Corps of Engineers standards, Natural Heritage standards, ADA standards, and town of Lancaster standards.
- Incorporate the importance of rivers & the history of the American’s with Disabilities Act into the project report.

5. PROJECT 2

- Develop more permanent pedestrian bridges spanning approximately 8 feet for two crossings along the nature trail.
- Design the pedestrian bridges and specify the necessary materials, project funds, and equipment required to complete the project.
- Ensure design takes into account endangered species, Army Corps of Engineers standards, Natural Heritage standards, ADA standards, and town of Lancaster standards.
- Incorporate the importance of rivers & the history of American bridge construction into the project report.

6. PROJECT TIMELINE

A Term:
- Weigh the pros and cons of the available projects and agree on a project to complete.
- Develop project objective.
- Develop project methodology.
- Complete necessary background research for the project we choose.
- Attend a Friends of the Lancaster meeting which occur on the 3rd Wednesday of the month from 6:30 p.m. to 8:00 p.m. at the town Library.

B Term:
- Continue researching project.
- Complete technical project work including all necessary designs, permitting etc.

C Term:
- Write project report which explains the significance of our technical work and connects it to the larger context of land conservation and river recreation.
7. PHOTOS

Photo 1: Site of Project 1. Handicap accessible picnic area to accommodate 6 picnic tables.

Photo 2: Clearing for high voltage power lines between site of Project 1 & Mcgovern Brook.
Photo 3: Fishing area approximately 1000 ft. from the entrance to the Cooks Conservation area.

Photo 4: One site of Project 2. Current pedestrian bridge spanning Mcgovern Brook.
SITE VISIT NO. 02

Date: 24 September 2014  
Time: 5:00 p.m. to 6:30 p.m.  
Location: Cook’s Conservation Land, Lancaster, MA  
Report By: JP Connors

1. PURPOSE
We visited the site to install a survey box and visit the second bridge crossing further along the trail.

2. General Observations
- We observed QR codes posted on trees and logs throughout the Cook Conservation Area. Upon scanning these codes we found that they are part of an online scavenger hunt called Munzee. According to Munzee’s website, “Munzee is the next generation in global scavenger hunt games. Simply download the free app, scan the munzees you find, and score points.” (munzee.com) The presence of these QR codes and the fact that the munzee app indicates the codes are regularly scanned indicates that the Cook Conservation Area has a fairly active user base.

3. Survey Box
- The survey box contains approximately 40 surveys designed by our team and features a laminated sign that directs trail users to fill out the survey. The sign explains who we are and why we are conducting the survey and it also has a QR code and web address so that trail users can fill out an online version of our survey.
- We considered potential locations for the survey box and decided that the right hand post of the trail map kiosk would be the best spot for the survey box.
- We used a screw gun and three screws to affix the survey box to the trail map kiosk.
SITE VISIT NO. 03

Date: November 10, 2014  
Time: 2:40 p.m. to 4:30 p.m.  
Location: Cook’s Conservation Land, Lancaster, MA  
Report By: Hannah Lee  
Project Team Members in Attendance: Jeremy Soderholm, Hannah Lee, JP Connors

1. PURPOSE

The purpose of this field visit was to mainly obtain soils from the two bridge sites for sieve and Atterberg analysis. Measurements of width and length of the current bridges were done for further assessment. Knowledge gained from soil tests and current bridge measurements will further assist us in planning and designing the construction of bridges. On this field visit pictures of the parking lot and entrance to the area as well as the bridge sites were taken.

2. Measurements

Bridge site 1:  
- This first site is 0.62 miles from the trail head. Hole was dug with depth of 14 inches.  
- Length of current bridge: 22’ 1.5”  
- Length of the bridge if it were placed in line with the trail: 23’1”

Bridge site 2:  
- The second site is 1.43 miles from the trailhead.  
- Sample hole dug out was 13 inches.  
- Length of current bridge: 16’  
- Max width allowed by current configuration: 5’7”
3. Photos

a. Photos were taken of the entrance to the area and the parking lot:
b. The first bridge site:
c. The second bridge site:
d. Sampling Soil:
1. PURPOSE
With snow fast approaching, it was imperative to conduct a topographic survey of the McGovern Brook bridge site. Elevation points around the bridge were taken and recorded to be placed into contour map of the area.

2. PERSONS CONTACTED
Russ Lang, Worcester Polytechnic Institute

3. GENERAL OBSERVATIONS
- The Cook Conservation Area is located on Lunenburg Road approximately 1.5 miles north of the intersection of Routes 117 & 70 in Lancaster, MA.
- Much of the stream was getting eroded and spreading wider.
- A large puddle at the entrance of the parking lot presented an obstacle for vehicles.
- Papers in the survey box had been distorted from saturation.

4. Results of Measurements
- Enough data was gathered to create several representations of the site.