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Space Invaders: Japanese Knotweed and the Restoration of Beaver Brook in Keene, New Hampshire

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This paper is dedicated to Lori and George Stringer, the parent's of Heather Stringer; Kelly and Al Lariviere, the parent's of Bryan Lariviere; Deborah and Lynn Taylor, and Lawrence Jones; parent's of Christine Jones; as well as the members of 8 Spruce Street, Nathan Cadenhead's friends. Without their patience, understanding support, and love the completion of this project would not have been possible.

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Abstract

In 2004, the City of Keene, New Hampshire, initiated a river restoration plan on one of its local waterways, Beaver Brook. Beginning at the Three Mile Reservoir in Gilsum, New Hampshire, the brook meanders its way through Keene before emptying into the Ashuelot River. The goals of the City of Keene are to: improve water quality of the brook; improve and restore aquatic riparian habitat; and provide public education and encourage public stewardship of the brook. This study locates linkages between residents of the City of Keene and the restoration of Beaver Brook, while providing education to the public regarding river restoration and awareness of the invasive species Japanese Knotweed. Primary data collection for this research involves: plotting locations of the invasive species Japanese Knotweed along Beaver Brook using Global Positioning System (GPS) receivers, and creating and distributing a survey instrument to gauge attitudes and awareness of Beaver Brook. The survey was distributed at the Source to the Sea River Clean-up, a meeting of the Southeast Keene Neighborhood Group, and handed out door-to-door to southeast Keene residents. Of the data that were gathered from the surveys, multiple tests were then run through SPSS (a statistical test program that helps to define areas of significant differences and relationships between data). Results reveal a significant difference between homeowners versus renters residing in and around the brook and numerous values regarding Beaver Brook. A second test shows that there is also a significant difference between age group respondents and the level of awareness of invasive species residing along Beaver Brook. Findings of this study are intended to benefit the City of Keene and any other municipality attempting to restore riparian habitats and educating the public on invasive species.

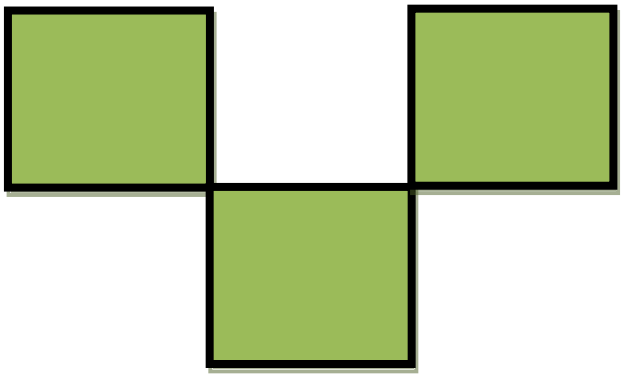
List of Figures

Figures

List of Tables

Tables

Table of Contents



Chapter 1:

Introduction

Invasive species, causal agents of disrupting and damaging ecosystems, are a leading hazard to the ecological stability of the United States. An invasive species is defined as "any plant, animal, or organism that is not native to the ecosystem under consideration and whose introduction is likely to cause harm to human health, environment, or the economy" (Faust 2001). Some invasive species are introduced to the environment intentionally, others unintentionally. Either method can lead to rapid expansion and dispersal. Due to the harmful impacts that invasive species can have on an ecosystem, eradication of the alien species and restoration of the natural habitat is critical to the overall state of infected areas. The adverse effect of invasive species in the United States has led to the formation and development of restoration efforts for wildlife ecosystems. As such, management and suppression of invasive species is exceedingly imperative. Unfortunately, the lack of instruction and economic capital throughout the United States limits the ability to control invasive species on a national scale. "The annual cost to the United States economy is estimated at $120 billion a year, with over 100 million acres suffering from invasive plant infestations" (The Nature Conservancy 2009).

Throughout the United States specific locales have participated in eradication efforts of invasive species, greatly enhancing the condition of specific ecosystems involved. Some of the leading participants in eradication projects include but are not limited to the San Marcos River in Texas, Bronx River in New York, and Kissimmee River in Florida. These river restoration projects demonstrate that control and elimination of invasive species can be an effective method utilized to rehabilitate ecosystems. Most invasive plant species reside along the banks of streams and rivers known as riparian areas. These areas are at high risk due to the instability of the river's edge caused by the invasive. Due to the riparian invasive species, these weak river

banks tend to deteriorate and erode along the rivers edges and begin to cause damage to the overall habitat. When alien species take over a specific area, they inhibit the native species that once thrived there, minimizing the amount of native species present. With a decline in growth of native species, animals that once thrived at those specific sites suffer. The animals do not have their typical food supply so migration to a new territory may ultimately be necessary for survival.

The San Marcos River in Texas removed invasive species by weeding, replanting of native species, and a strict monitoring process to ensure that the restoration process was effective. This project was completed by the San Marcos River Foundation and local community groups (Texas State University 2004). The Bronx River in New York, organized and maintained by The Bronx River Alliance, similarly relied on weeding, but also utilized herbicides, and repeated cutting as part of restoration efforts (New York City Department of Parks and Recreation 2009). The Kissimmee River in Florida was invaded with alien species after the US Army Corps of Engineers constructed a flood control project which later resulted in drastic ecological damages (South Florida Water Management District 2009). These circumstances provide a future indicating that invasive species removal can be successful.

Data on river eradications have prompted further locations to take part in accomplishing the same success. The City of Keene, New Hampshire, which serves as the focal point of this study, is taking considerable efforts towards restoring a local brook. This restoration plan has been put into action with a vision to not only restore the brook but also to educate and engage local residents of the community during the restoration process. Due to Beaver Brook's relatively small size and the environmental ethos held by the City of Keene, the brook is an

appropriate candidate for the restoration process. As invasive species and pollution continue increase within the Beaver Brook floodplain, Keene citizens and city officials cooperate to collectively re-establish the brook to an improved state. With community cooperation the brook once again will become another scenic location for Keene residents to enjoy.

Both the community and ecosystem surrounding Beaver Brook will greatly benefit from the restoration plan. Reintegration of native species will return Beaver Brook to its original state, before pollution and invasive species littered the area. The development of invasive species eradication and pollution control can considerably develop the usage of Beaver Brook. This restoration aims to improve the ecosystem by providing aesthetically pleasing landscapes, reintegration of native species, and reintroducing aquatic life. Beaver Brook has two prominent invasive species that are corrupting the locale. The first is Japanese Knotweed, the central focus of this investigation, and the second invasive species is Purple Loosestrife. Although both of the invasive species are important to the restoration process of Beaver Brook, Japanese Knotweed is the specific focus for this project. City officials requested that the focus be placed on the invasive plant Japanese Knotweed, an herbaceous perennial that resides along the banks of bodies of water. Japanese Knotweed is currently controlling most native plant species of Beaver Brook, as well as aquatic life, and the animals residing along the brook. As part of the restoration plan, the City of Keene and local residents hope to re-introduce the native species that once existed there, while reducing pollution of the water which will improve the wellbeing of aquatic and plant species.

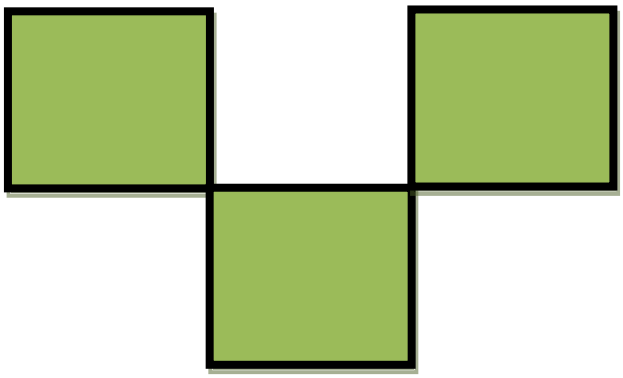
Focal Questions

This study intends to provide an in depth spatial analysis of Japanese Knotweed locations, particularly, where along the Beaver Brook floodplain is Japanese Knotweed located? This study also gauges Keene residents and Keene State College students' attitudes regarding the Beaver Brook restoration plan. This study attempts to identify what the community would specifically like to implement in the restoration process and the community's desired result. Ranking the residents agreement with specific issues surrounding the brook and a brief analysis of what the surveyed respondents believe is the best and worst things about Beaver Brook is also looked upon in detail.

Hypotheses

This study is composed of multiple components which identify the issues involved in the restoration of Beaver Brook. The fieldwork conducted regarding Beaver Brook includes locating Japanese Knotweed and plotting various GPS coordinates. Also, pH level testing of randomized outfalls along Beaver Brook is provided. Primary data collection through original survey analysis affords ability to test statistically several hypotheses specifically,

- Residents of Keene who are renters will have significantly lower awareness levels of invasive species residing along Beaver Brook.
- Keene residents living in the Beaver Brook floodplain are most likely to be aware of Keene's ongoing plan to restore Beaver Brook.
- Homeowners are more likely to be willing to financially support the restoration plan.
- Keene State College students and Keene homeowners will rate the aspects of Beaver Brook much differently when it comes to periodic flooding, reintegration of native species, aesthetics, eradication of invasive species, water quality, and finances. The Keene State College students will have little opinion about these topics.



Chapter 2:

Literature Review

Background

River Restoration efforts are very diverse and may include, flood control, eradication of invasive species, improving water quality, and habitat enhancement. The City of Keene may benefit by following similar efforts to achieve restoration fulfillment. Several analogous studies dealing with like issues that face Beaver Brook have allowed for a thorough plan of action to be proposed. These previous student provide insight that deal with predicaments that may not be foreseen in the restoration process. Comparable studies contribute to the efficiency of restoration projects by providing a template of relevant issues that are practical in applications regarding the area of concern. This chapter, therefore, highlights the principal studies associated with the problems and prospects of river restoration.

Invasive Species: Japanese Knotweed

An increasing amount of attention is being directed toward the issue of invasive species that have become a nuisance to river systems. These non-indigenous species adversely affect the habitats they invade both: economically and environmentally. Located within 42 of the 50 United States, one of the most abundant and rapidly growing invasive plants, Japanese Knotweed, also resides in Keene (United States Department of Agriculture 2009a). Japanese Knotweed is a rhizomatous and herbaceous perennial plant native to Japan, China, Taiwan, and Korea (Bram and McNair 2004). It is one of the most attractive and lush invasive species found throughout the world; particularly during the spring and summer months, when it is flowering. The systematic and nomenclature of Japanese Knotweed are widely disagreed among different countries. There has yet to be a single scientific name that has gained international acceptance

for this invasive plant. Around the world, Knotweed is variously referred to in current literature as *Polygonum cuspidatum*, *Fallopia japonica*, and *Reynoutria japonica* (Weston et al. 2005; Dassonville et al. 2007; Maurel et al. 2009). The most commonly known name used in the United States is *Polygonum cuspidatum*.

Several similar studies have been conducted in previous years regarding the presence of Japanese Knotweed within river systems. Efforts are currently being made to help eradicate the riparian invasive species along the Lamprey River; located in Northwood, New Hampshire. Volunteers and officials from the Lamprey River Watershed Association (LRWA) are taking aim at the persistent plant which threatens to obscure some of the scenic pathways near the region's largest tributary. Director of the LRWA, Dawn Genes, determined that the invasive species was noted at some 51 locations along or near the Lamprey River, when dozens of volunteers conducted a shoreline survey of the river during the summer of 2008 (Henry 2009). In addition, the Lamprey River Advisory Committee (LRAC) has been working in partnership with the LRWA, to organize an ongoing effort to eradicate Japanese Knotweed from the river. Both committees reported that the invasive plant has been appearing in more and larger stands along the river, consequently taking over significant areas of native habitat (LRAC 2008).

Similarly, a 2003 study has been conducted regarding the Deerfield River, originating in Deerfield, Massachusetts. Japanese Knotweed was found to be very abundant along this river. The Deerfield River Watershed Association (DRWA) completed surveys for the invasive plants on eight of the river's tributaries between the months of April and June of 2003. Results revealed that Knotweed plants were found growing on the stream banks of seven out of the eight tributaries. Four of the river's tributaries had severe infestations of the Japanese

Knotweed (Serrentino 2003). The DRWA's project summary indicated that Japanese Knotweed infestations were abundant and well-distributed in the riparian areas associated with several rivers and streams in the watershed. Sites that had little or no knotweed were located in isolated areas and away from roads. It was found that the downstream areas had severe or moderate infestations. Serrentino in 2003 noted that the invasive plant is more abundant at locations adjacent to roadways, due to an increase in disturbance to the river bank.

Control Methods

Because the invasive species, Japanese Knotweed grows and spreads at such a rapid rate, it has been found that it is difficult to both control and eradicate the abundant species. Past research studies have been conducted to help implement management methods in order to help eradicate Japanese Knotweed. Research shows that there are three major methods of managing Japanese Knotweed; mechanical, chemical, and biological control.

Mechanical control consists of the acts of digging, mowing, and/or hand pulling. This method is generally useful for localized areas only because of its time constraints. Plants are physically removed from the water body when using any of the three methods of mechanical control. It is very labor intensive and only useful for small infestations. Therefore, mechanical control is not practical when plant growth is dense (NHDES 2001). The Lamprey River Restoration Committee in Northwood, New Hampshire, has attempted the mechanical control method in and along its river. Several homeowners and road crews routinely mow and pull the invasive plant along the banks of the Lamprey. However, the committee found that this method does not do much to eliminate the plant permanently (Henry 2009).

Chemical control is another popular invasive species control method used in efforts to potentially eradicate the invasive species, Japanese Knotweed. This method commonly uses herbicides such as, piclroam, glyphosate, and imazapyr, as well as various other sprays to help eliminate Japanese Knotweed (Stone et al. 2005). If used appropriately, chemical control has potential to eliminate the exotic plant infestation. This method has been found to work at a relatively rapid rate. However, the chemicals are generally harmful to the water body that they are used around and could potentially impact non-target species if not applied correctly (NHDES 2001). A project committee in northeast Scotland has successfully eliminated Japanese Knotweed by means of chemical control along the Ythan River. However, unknown chemical sprays were used to remove the Japanese Knotweed from the Ythan River before it got to a foothold (Aberdeenshire Council 2005).

The third commonly used invasive species management method is biological control. Over the past few years, host specificity of foreign natural enemies is becoming more and more critical in biological control management. This specific method is effective against target plants and does not affect other non-target species. Since most chemicals and pesticides cannot be used when restoring a stream, several restoration committees turn to this control method in hopes to successfully eliminate Japanese Knotweed. A potential promising agent for control of Japanese knotweed that is currently being used in the United States is a leaf beetle called, *Gallericida bifasciata* (Wang et al. 2008). The beetle is used to eat the leaves off the Knotweed, which eventually kills the plant. This specific method however is currently under the trial phase to guarantee its effectiveness. Therefore, it is not yet ready to be widely used. There are hopes

for the use of *Gallericida bifasciata* to become an effective and efficient method to eradicate Japanese Knotweed in the near future (Wang et al. 2008).

Water Quality and Aquatic Life

Another serious issue that rivers face is poor water quality. Thousands of rivers across the globe contain polluted waters, many worse than others. Marine life, including fish species are being killed off due to this environmental problem. Several states among the United States have taken further actions to try to control pollution in its rivers. Maryland currently has a law in effect that does not allow roads to be paved along the Chesapeake Bay area. The Clean Water Act amendments address pollution issues, such as toxic runoff and pesticides, to help inform communities of the dangers of polluted waters, as well as ways in which to prevent this disastrous occurrence. A 1988 study revealed that 30% of rivers and streams are too polluted for people to use, some even containing a specific bacterium that can lead to a deadly disease, *Escherichia Coli*, otherwise commonly known as *E. coli* (Miller 1992).

Millions of dollars are spent annually in hopes to restore aquatic habitat among polluted river systems. In the United States, a dominant amount of this abundant amount of money is being spent on rivers located primarily within the Pacific Northwest (Roni et al. 2002). Though, in Boone, North Carolina, the South Fork New River is currently experiencing a significant loss of fish habitat due to polluted water in the river. The river restoration committee is collaborating methods and ideas that will enable them to restore aquatic life into the South Fork New River (Benke 1990). There is also a recovery program for the Upper Colorado River Basin that is working on reintroducing specific endangered Colorado River fish into its river system. The

endangered fish that the committee is trying to reintroduce in the basin are the Razorback Sucker, Humpback Chub, Bonytail Chu, and the Colorado Pikeminnow (RiverRestoration.org 2008).

Recent studies reveal that air pollution is another major factor to consider in water pollution. Aquatic ecosystems are faced with acid, nitrogen, and mercury in the waters that comes from air pollution. If water bodies are too acidic, the aquatic life living within the river will eventually die off, resulting in a "dead" body of water. Mercury also kills off the different aquatic species that live in the ecosystem. Not only does this have a negative effect on the aquatic habitat, but it can also change the food chain within rivers (Lovett and Tear 2007). Rivers across the United States that are polluted need to be cleaned up in efforts to save aquatic life before it is too late.

Channelization

According to Andrew Brookes (1988), river channelization is the "processes of river engineering for the purposes of flood control, drainage improvement, maintenance of navigation, reduction of bank erosion to relocation for highway construction." Channelization is widely used throughout river systems in efforts for restoration. In 1992, Congress authorized the Water Resources Development Act to implement the Kissimmee River Restoration Project, located in Southern California. This specific project was designed to restore the hydrology and water quality of the 40 miles of meandering river channel and over 12,000 acres of wetlands in effort to reverse the degradation caused by channelization of the river for flood control in the 1960s. The Kissimmee River Restoration construction includes levee removal, water control,

structure improvements, flood protection, and various infrastructure improvements within the project zone. The channelization of the Kissimmee River lowered both average and peak flood stages, reduced and eliminated water-level fluctuations, and drastically modified discharge regimes throughout the basin (Toth et al. 1998). The Kissimmee River Restoration Project is the largest and most expensive river restoration project attempted so far (Koebel 2006).

On the other hand, channelization is not always a good idea and has long been a concern. Plans by the United States Army Corps of Engineers to channelize the Missouri River from Sioux City to Yankton have concerned local ecologists. The channelization of the last remaining natural stretch of the Missouri River below the main stem reservoirs could prove to be ecologically disastrous. There is also a high risk for a decrease in population levels of certain aquatic life. Ecologist fear that species could eventually be eliminated altogether from the river (Kendle 1970). Further research indicates that channelization of rivers reduces the variety of aquatic habitat by destroying key organism producing areas. Luckily, the detrimental effects of channelization can be lessened by preventing the destruction of chutes and sloughs, which are two important components in producing aquatic organisms (Kendle 1970).

Economic Costs

Currently, over 50,000 foreign species are invading the United States and costing the government over $120 billion annually (Pimentel et al. 2009). There is no question that this issue is a national priority. In the Pacific Northwest region of the United States, millions of dollars are spent annually on watershed restoration and stream habitat improvements, in an effort to increase the aquatic populations alone (Roni et al. 2002). However, millions of dollars

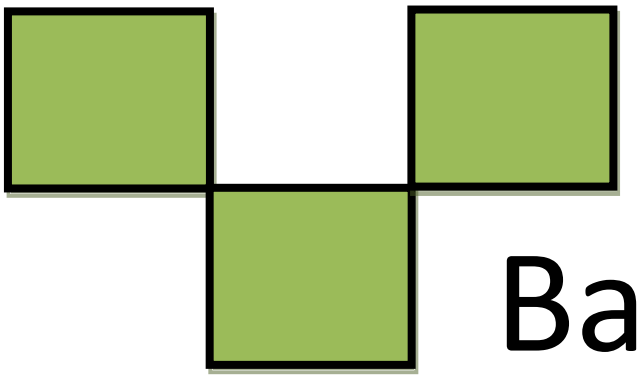
are spent annually in other portions of the United States. The Kissimmee River Restoration Project, located in Florida, is the largest and most expensive river restoration project that has been attempted so far. The Kissimmee River has well over $100,000 invested in its river's restoration project (Koebel 2006).

Several river restoration plans receive a lot of money from the government in efforts to help fund the rivers in need. When the Lamprey River Committee was forced to turn to other methods of management control, the State Department of Agriculture, Markets, and Food rewarded the committee a $12,000 grant. The grant that they received was used towards a chemical control for Japanese Knotweed. The knotweed-killing spray was used on groups of plants in Epping and Lee, New Hampshire that has completely eradicated the invasive species, Japanese Knotweed from these areas.

Concluding Statements

Efforts to restore Beaver Brook are present in the city of Keene, New Hampshire. There are several other efforts that have been implemented to rivers around the globe. Each restoration plan is unique to its own, and contains individual ideas, needs, and implications that will help restore its river. Among the many issues regarding river systems, invasive species, water pollution, and flooding are three major elements that receive heightened attention. Many rivers are losing aquatic life due to these issues and are a major concern to the future of several aquatic habitats within river systems. River restoration plans tend to become very costly and require a large amount of government support. However, there have also been cost effective ways in order to preserve the rivers. In summary, it is generally agreed that the

reason for restoration is to restore, enhance, and preserve the water environment of river systems throughout the world.



Chapter 3:

Background to Keene, New Hampshire and Beaver Brook

The City of Keene is centrally located within Cheshire County, in southwestern New Hampshire (Figure 1). Originally named Upper Ashuelot, the City of Keene (then a territory) was first granted to soldiers fighting in wars against Canada in 1735. Keene was the name given to the Upper Ashuelot by Governor Benning Wentworth out of his appreciation and high regard for Sir Benjamin Keene, who as a British minister to Spain, used his influence to help the Governor obtain payment for timber delivered at Cadiz (Proper 1968). In 1753, the establishment of the Massachusetts-New Hampshire state boundary made it one of the largest towns in New England. In present day Keene, residents are no longer fighting against other countries for land; they are fighting a battle against the perils of inefficiency and wastefulness, a battle to achieve a harmonious sustainable community.

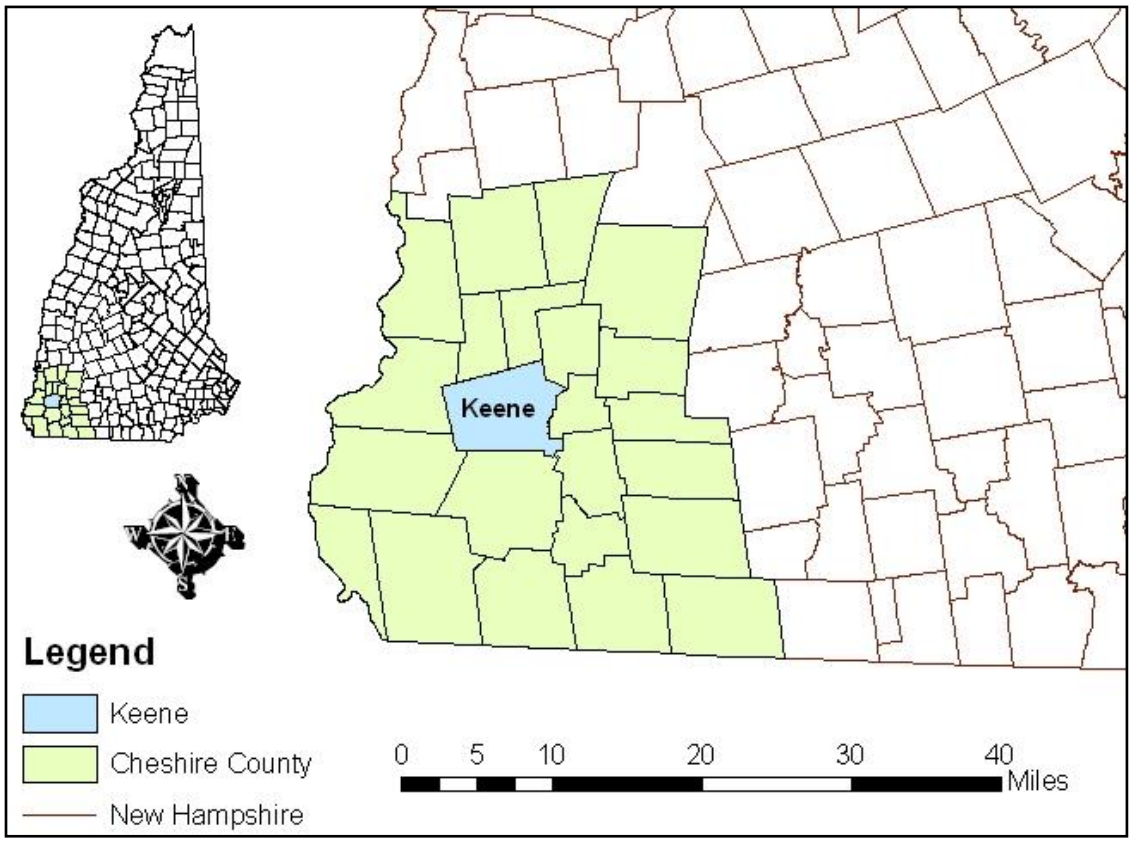


Figure 1 *Relative location of Keene, New Hampshire*

Keene is a relatively small city, home to 22,407 residents, 5,282 of which are college students enrolled at Keene State College (U.S. Census 2008; Keene State College 2009). The population of Keene is composed of several different ethnicities although the overwhelming majority is white at 97.9 percent. Located in a 'college' city, Keene's population is well educated with 37.7 percent of the total population possessing an Associate degree or higher (U.S. Census 2008). However the future of its population seems a bit misleading. Figure 2 reveals that the Baby Boomers will make up the majority of Keene's aging population in the next 20 to 30 years. This poses a problem due to the fact that there are less young adults to take care of an aging population. There are a higher amount of young adults ages 15-24, but this is due to the number of college students residing in Keene. It is to be expected that the majority of students will not be living in Keene post graduation, posing a potential dilemma to Keene in regards to the growing number of elderly residents.

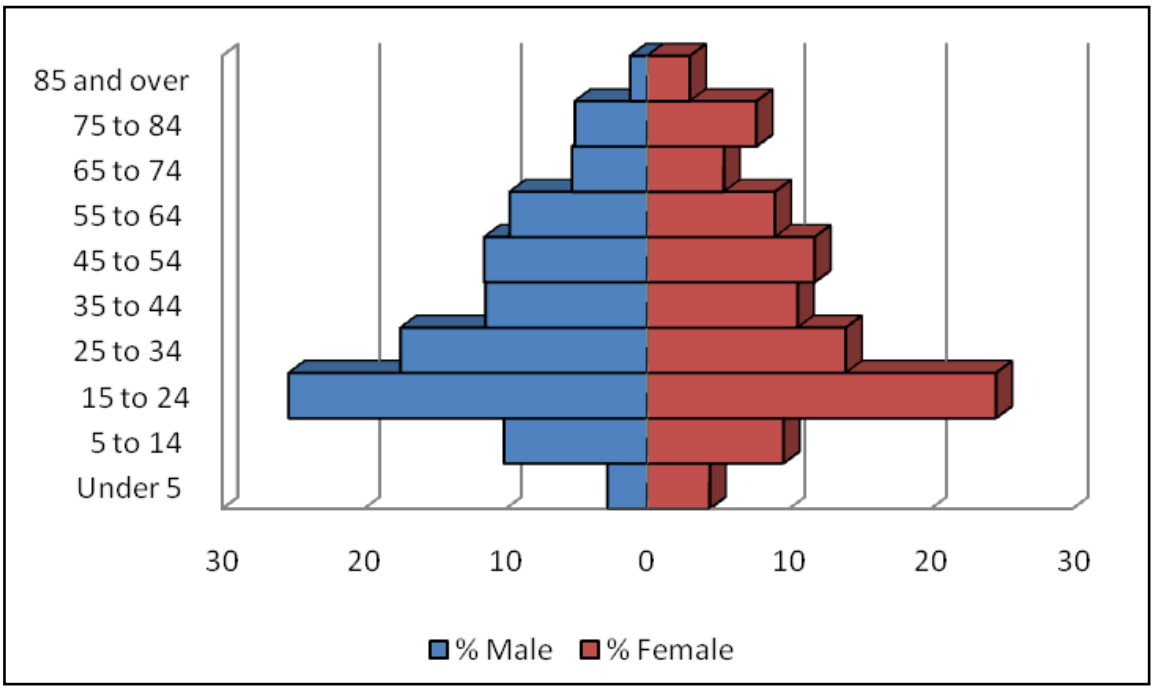


Figure 2 *Population Pyramid of Keene, New Hampshire* (2006-2008 U.S. Census Estimate)

While Keene serves as the heart of Cheshire County, at the heart of Keene itself is the city's Central Square. This public space, which is located at the North end of Main Street in downtown Keene, has recently been designated by the American Planning Association (APA) as one of Ten Great Public Spaces for 2009 within the United States. These 'Great Public Spaces'… "exemplify exceptional character and highlight the role planners and planning play in creating communities of lasting value" (City of Keene 2009a). Keene does indeed exemplify a community of lasting value, not only in civic affairs, in its commitment to becoming a 'green' city as well. Keene possesses a dedicated awareness of environmental issues and is very active in its efforts to become a truly sustainable city.

Keene's award winning community encompasses many of the qualities of a green city. The cohesion and commitment between the community and the college produces skilled and knowledgeable members who take action in many of the community's green programs. These programs and activities suggest that the community is cognizant of the need to become sustainable. As such, Keene is able to facilitate the needs of its community and provide a place for the future of Keene to exist in a maintainable locale.

Being so green is not so easy, however. Only through a collaborative effort has the City ascended to become a role model for surrounding areas. Figure 3 illustrates the key components that contribute to a sustainable Keene, New Hampshire. Local businesses not only provide jobs for residents, they add to the sustainability of Keene by following strict Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) policies. Some local businesses in Keene are taking an additional step by participating in the city's *Ten Percent Challenge* (City of Keene 2009d). This program challenges local

businesses to reduce greenhouse gas emissions by a minimum of ten percent, and supplies the tools and knowledge necessary to preserve energy in the workplace. The challenge was first mentioned in the Keene Cities for Climate Protection Local Action Plan (2004) which was fashioned by the City of Keene as a member of the Cities for Climate Protection Program. The Cities for Climate Protection Program is overseen by Local Government for Sustainability (ICLEI), on which the City of Keene has been a member since 2000. The program is made possible by the partnership among ICLEI, Clean Air-Cool Planet and Keene's Cities for Climate Protection Committee (CCP) (City of Keene 2009d).

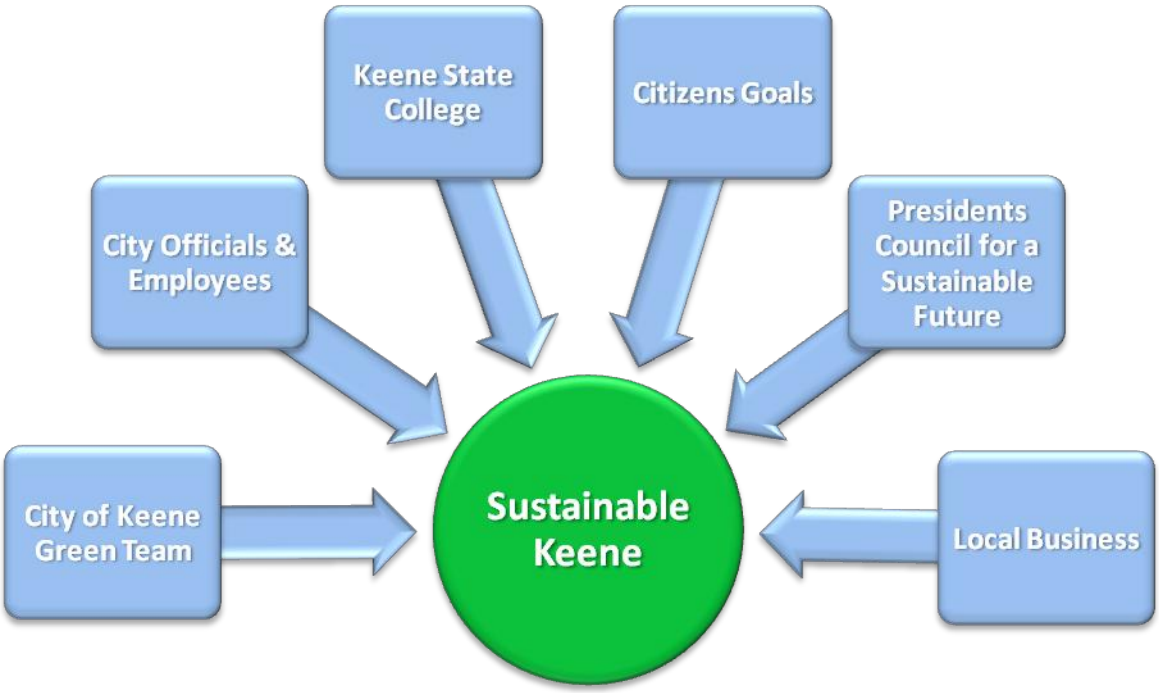


Figure 3 *Relationships that contribute to a sustainable City of Keene*

City of Keene Green Ethos

'The City of Keene Green Team' was assembled by the City of Keene, composed of city officials and city employees to address environmental issues. The Team establishes

comprehensive plans suggesting targets, timelines, and measures to be taken in order to reach short to long term objectives. The team delineates recommendations to the public to support goals and progress towards sustainability. The overall mission of the team is to review, evaluate, and suggest recommendations to the City Manager regarding prospects to attain a greater rank of environmental sustainability. Only through utilizing energy efficient systems, reducing Keene's carbon footprint, concentrating on more efficient resource utilization (people, facilities, infrastructure, utilities), and developing and/or acquiring technology will Keene continue to succeed in obtaining its goal as a sustainable city (City of Keene 2009b; Prokop 2009).

The Environmental Preferable Purchasing Program (EP3) currently being practiced by the City requires departments to consider using products that have a lesser or reduced effect on human health and the environment when compared with competing products that serve the same purpose (City of Keene 2009d). The Woodstove Changeout Program has been implemented to reduce emissions by residents of Keene who utilize woodstoves that are uncertified as a primary or secondary source of heating. A $1,000 voucher is being given out to residents who meet the requirements for exchange towards a new, certified wood, pellet, or gas stove (City of Keene 2009c). Through this program alone the City of Keene will: reduce fine particles and toxic air pollution by 70 percent; reduce indoor PM2.5 (fine particles) emissions by 70 percent; help the State of New Hampshire earn State Implementation Plan emission reduction credits; improve energy efficiency by 50 percent, by using one third less wood; and, reduce methane and carbon dioxide (EPA 2009).

Keene State College Green Ethos

The Keene State College (KSC) community (6,000 plus, including all students and faculty) also exemplifies the meaning of 'green'. The College's President's Council for a Sustainable Future (PCSF), whose motto is "Global Thinking. Local Action", works to aid Keene in achieving a sustainable community. The PCSF, "Affirms the beliefs that college faculty, staff, administration and students have a responsibility to take a leadership role in conducting activities as responsible stewards of the environment" (Keene State College 2009a).

The PCSF sanctions green programs that are implemented at the college. For instance the KSC Green Bikes program provides free bike rentals not only students, but also to community members who need a mode of transportation. These bikes can be checked out like a book at the Mason Library. Fifteen bikes are currently in circulation and are available to anyone who possesses a valid Keene State College or City library card. The bikes themselves were collected throughout Cheshire County, fixed up and painted green. This program was instituted in 2002 by the Campus Ecology group and several Keene High School students. KSC Green Bikes program has provided an alternate mode of transportation for community members and is aiding the city on emissions reductions.

Another way the PCSF is fighting a winning battle against emissions is by the use of alternative fuels in vehicles owned by the college. The college uses electric vehicles, hybrid vehicles and straight bio-diesel vehicles. According to Arthur Winsor, Assistant Director of Physical Plant at Keene State College, the alternate fuels used in vehicles at the college, an 80-20 blend of gasoline and bio-diesel, are less harmful to the operators and bystanders around them. The use of these alternate fuels also prolongs the engine life of machinery and vehicles.

These fuels are purchased locally through Rymes Propane & Oils, Inc. in Swanzey, New Hampshire. This, Winsor says, reduces costs of purchasing from foreign producers and helps support local business.

Recycling on Campus at Keene State College (R.O.C.K.S) is a Keene State College program that was introduced some 30 years ago. The mission statement of R.O.C.K.S presents a green approach to assist the community in maintaining a sustainable City of Keene.

> The mission of R.O.C.K.S. is to educate the community about solid waste issues, promote environmental awareness and economic growth through recycling and achieve diversion rates set by government through reduction, reuse, and recycling (Keene State College 2009b).

R.O.C.K.S offers students and faculty numerous ways to "go green", including a Green Guide that presents the college community with ways to save money and energy while gaining knowledge on becoming a sustainable community. Numerous areas of the college community fall into the sustainability category. Those areas include but are not limited to; energy and utilities, environmental literature and activities, hazardous waste, networking and communication, campus planning, solid waste, purchasing, transportation, landscape, and contract services (Keene State College 2009c). With sustainability integrated into many different realms of the college KSC is a forerunner in the pursuit for an environmentally-sound community.

Behind the college and the City of Keene is a population dedicated to the sustainability for the good of the community. With the establishment of environmental friendly green programs and the initiative to follow through with such programs, Keene has become a leader and model for those in the pursuit for a sustainable community. The City's dedication to its

community when dealing with environmental concern continues to be first rate. As the City deals with the issue of restoring Beaver Brook the same involved, supportive, forward-looking, concomitant, community will unite once again to advocate for the sustainability of the City.

Background to Beaver Brook

Beaver Brook, a tributary of the Ashuelot River, is located on the eastern side of Keene, New Hampshire. The brook begins at the Three Mile Long Reservoir in the town of Gilsum and meanders its way through Keene before emptying into the Ashuelot River (Figure 4). Beaver Brook is not a very wide body of water; however it does include some sections that stretch an estimated fifteen to twenty feet across while flowing through the town. Areas that have not been channelized and where beaver populations have built dams, such as in the section of brook that runs through the Woodlawn Cemetery, can get particularly wide during the rainy season.

Aside from the beaver population, there are many animals that use the brook for habitat and food. Some of these animals that make the Beaver Brook watershed their habitat are fish (Figure 5). In addition to the animal population, humans use the brook as well. People that reside next to the brook use it as a source of play and recreation. For instance, some residents walk their dogs along the brook while children play near the water. A major appeal that brings residents to the banks of Beaver Brook is the Woodlawn Cemetery. The brook traverses the cemetery where local residents walk, bike, and jog.

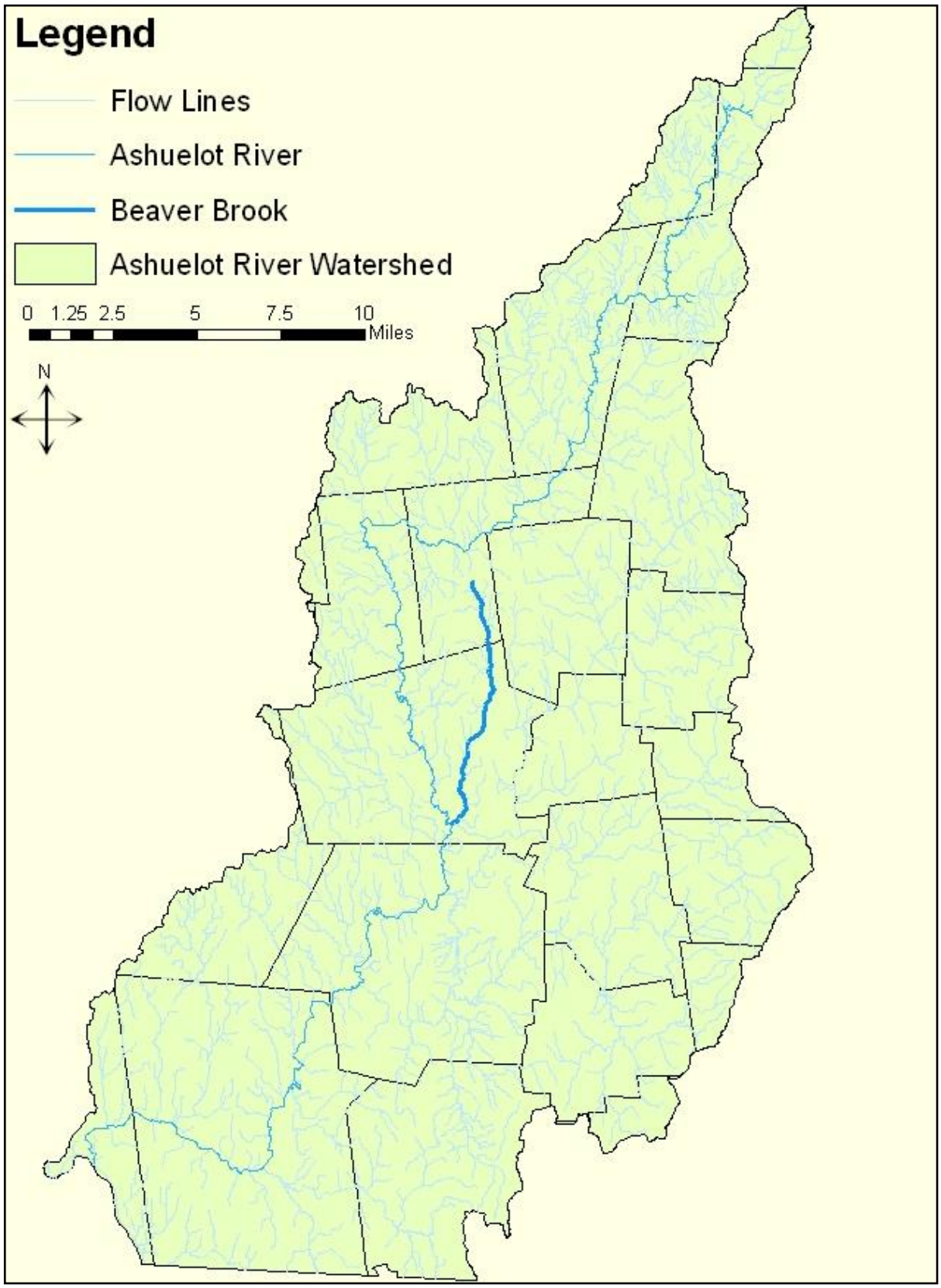


Figure 4 *Relative location of Beaver Brook*

Figure 5 *Blue Heron Residing in the Brook*

Although Beaver Brook serves as a natural amenity, it is not without problems. These problems include pollution, flooding, invasive species, and water quality. This study focuses primarily on the problem regarding riparian invasive species. Riparian invasive species are non-native plants that take over native plants in an aquatic ecosystem. A riparian zone is the land located along the sides or banks of an aquatic ecosystem, including rivers, streams, and brooks. These zones are important natural biofilters, protecting aquatic environments from excessive sedimentation, polluted surface runoff and erosion (Tang 1995). Plants and trees thrive here because of the abundance of water and nutrients. In the riparian zone surrounding Beaver Brook there are many invasive species that are taking over native species. Two of the more abundant invasive species in the area are Japanese Knotweed *Polygonum cuspidatum* and Purple Loosestrife *Lythrum salicaria*. That these two invasive species have taken over much of

the banks of Beaver Brook has created havoc for native plants that are trying to thrive. In this study, Japanese Knotweed is the main concern.

Japanese Knotweed (*Polygonum cuspidatum)*

Japanese Knotweed is known as one of the most successful plant invaders, spreading itself over several continents (Lecerf 2007). Some of the countries and continents infected by the invasive species are Europe, United States, Canada, Australia, and New Zealand (Urgenson 2006). In the United States more than 40 states are affected by Japanese Knotweed. Figure 6 shows the states affected by Japanese Knotweed.

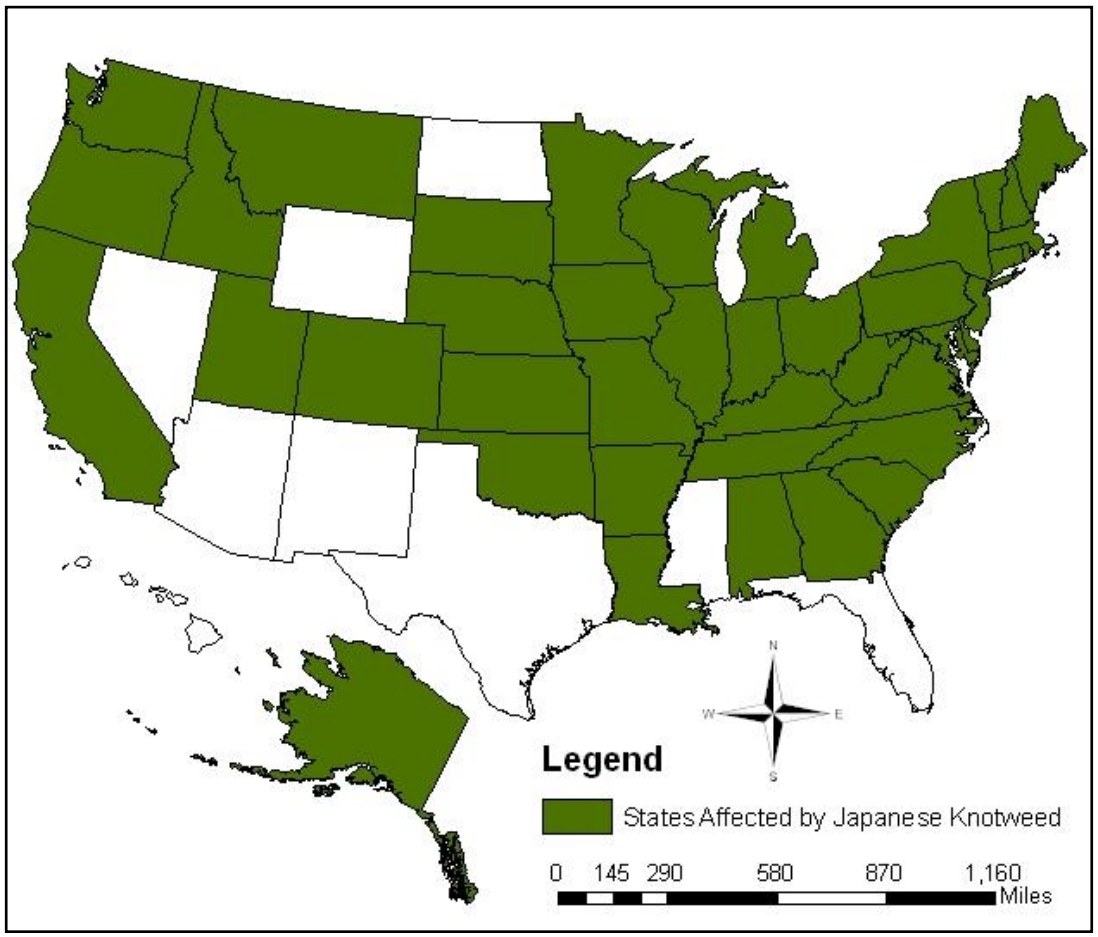


Figure 6 *States Affected by Japanese Knotweed*

Japanese Knotweed also known as *Polygonum*It introduced to Europe and North America in the middle 1800's (Lecerf 2007). This plant was introduced in North America and the United Kingdom as an ornamental plant used for its looks, but it quickly spiraled out of control. As seen in Figure 7, Japanese Knotweed can be distinguished by its heart shaped leaves and bamboo-like stems. The bamboo-like stems grow upright and can reach a height of five meters or sixteen feet (Weston 2005). The stems on the Japanese Knotweed can be red, brown, or green in color and form thick bamboo stalks as the plant grows older (Weston 2005). These stalks make the patches of Japanese Knotweed very thick and dense which crowds other species of plants. Forming in spring and budding during the late summer in North America, the flowers are that of a cream and white color, which form in clusters along the branches of the stalks (Urgenson 2006). The flowers are pollinated by bees and other insects. Seeds of the knotweed appear several weeks after flowering and are transported by the wind. Even though these plants are very pleasing because of its aesthetics, it is still very much an invasive and growing problem.

Figure 7 *Japanese Knotweed along Beaver Brook* (Source: Authors)

Japanese Knotweed thrives in the highly disturbed areas, more commonly along roadsides and riparian zones. In the United States, Japanese Knotweed is found prevalent along the east coast stretching from Georgia to Maine. It is also found across the central United States and into the Pacific Northwest (Weston 2005). Japanese Knotweed is successful in invading and spreading because its rhizomes, or underground roots, can reach seven meters (22 ft) in length and two meters (6.5 ft) in depth (Weston 2005). These underground roots are very tough and can grow in very diverse conditions. In fact, the rhizomes of the knotweed are so tough that they can break through driveways, house foundations, and even concrete sidewalks (Urgenson 2006). These underground roots make Japanese Knotweed a successful and prevalent invasive species because knotweeds are able to regenerate from a piece of rhizome as small as seven grams (Urgenson 2006). This, in turn, makes eradicating or removing this plant exceedingly difficult.

Other factors that contribute to the success of Japanese Knotweed are the thickness of its canopy and stem litter. As seen in Figure 8, the canopy (top of the plant) of the knotweed is so thick that it blocks out sun and nutrients for other plants trying to survive next to the knotweed (Urgenson 2006). Stem litter consists of leaves, flowers, and parts of the stem that fall onto the ground due to wind, rain, and death of the plant. This litter can blanket the ground covering any other plants trying to grow which leads to the increased growth of the knotweed. Japanese Knotweed thrives and spreads most rapidly along riparian ecosystems because floodwaters often pick up rhizome fragments and transport them downstream (Urgenson 2006). This allows the knotweed to start new colonies wherever the stems are

deposited. With the success of the knotweed, researchers are trying to determine the most effective way of eradicating the plant.

Figure 8 *Canopy of Japanese Knotweed along Beaver Brook* (Source: Authors)

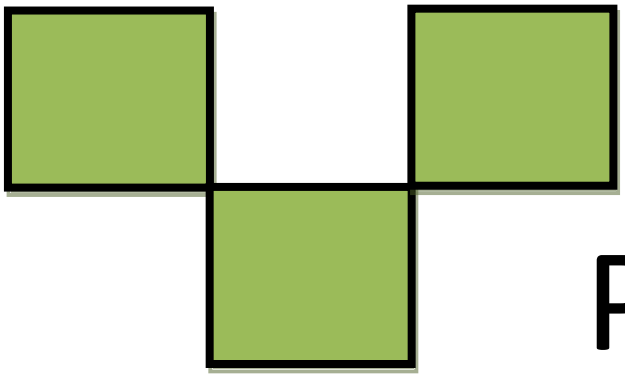
Controlling Japanese Knotweed can be a very tough and painstaking task. Some of the measurements to control the knotweed include mowing, cutting the stalk, herbicides, manual pulling, and even an insect called the *Gallerucella* beetle. While, mowing, cutting, and pulling are the most common forms of removing the knotweed, the most common may not be the most effective. Mowing is not an effective way of eradicating Japanese Knotweed because mowing causes disruption and it tears the knotweed apart. Tearing the plant apart is not successful due to the fact that knotweed can regenerate from tiny pieces of rhizome, and mowing just shoots those rhizome pieces in all directions. This can actually lead to an increased

rate of spreading of the knotweed. Cutting the stalk and pulling the plants are both treatments that have mixed success. Cutting the stalk does not eradicate the plant entirely because there are still roots for it to grow, though this act does slow down the growth of the invasive. Cutting three times a season and using topsoil or mulch to cover the stalks will slow the growth of the invasive, but completely removing the plant is out of the question (Urgenson 2006). Pulling the plants is also a mixed success because during the act of pulling the plant out of the ground, parts of the rhizome or root might be left in the soil which will lead to re-growth.

The application of herbicides is another form of removal, yet this is an exceedingly painstaking task. The most effective way of using an herbicide is to cut the stalk and manually inject a biodegradable herbicide (Ford 2004). This task is manually labor intensive because two people are needed; one to cut the stalk and another to apply the herbicide. The appropriate herbicide needs to be used in this instance because the wrong herbicide will cause more damage to surrounding plants and water. If performed correctly, this procedure is a quite effective means of control. One other interesting means of control is the introduction of insects into the area of infestation. A beetle that is being studied more and more for means of controlling knotweed is the *Gallerucida bifasciata*. This beetle has been proven to prefer Japanese Knotweed over other plants and is being looked at as a means of control, although it is still under contemplation (Wang et al 2008). The use of insects, such as this beetle, is a more environmentally safe and less painstaking task of cutting or using herbicides. When it comes to Beaver Brook many of these means of control have been studied and even implemented, such as mowing and cutting, but research for the restoration process of the knotweed is still being conducted.

Concluding Paragraph

The restoration of Beaver Brook, started in 2004, is still in the research and developmental stages, and is going to take years to complete. Some of the challenges faced are improving the water quality, removing riparian invasive species, and educating the public about the brook. Out of all the problems faced by the City of Keene, perhaps the most challenging and arduous task is removing and eradicating the invasive species Japanese Knotweed. Japanese Knotweed is found in many locations along the brook and creates mayhem to the entire riparian ecosystem. The knotweed is a very aggressive invader and will take over large portions of the brook. In order to successfully remove the knotweed, many hours of research and field work is needed. The quantity of Japanese Knotweed along the brook makes it very difficult to successfully remove and eradicate the plant. Educating citizens about invasive species in general and specifically Japanese Knotweed is one step closer to completing the restoration process.



Chapter 4:

Primary Data Collection and Analysis

Restoration of Beaver Brook

The restoration of Beaver Brook in Keene was initiated in 2004. The goals of the restoration project are to; improve the water quality, improve and restore aquatic riparian habitat, provide public education, and encourage conservation of the brook (City of Keene 2009f). The water quality restoration deals with three problems; trash and debris in the brook, non-point source pollution or runoff, and bacteria in the water. Steps to take care of these problems started in 2007 when the City of Keene joined the "Source to the Sea" cleanup with the Connecticut River Water Council (City of Keene 2009h). This cleanup takes place once a year and attracts volunteers of all ages. All tributaries of the Connecticut River, including Beaver Brook, are included in the cleanup. The next goal of the City of Keene is the improvement and restoration of the aquatic riparian habitat. According to Mr. Will Schoefmann of the Keene Planning Department:

> Keene has been working for the past few decades to restore and clean up our major urban waterways such as Beaver Brook and the Ashuelot River. However, I would say that the restoration project is the City's first comprehensive attempt to tackle the specific issues surrounding Beaver Brook (Personal Communication, 2009).

Being the city's first attempt to tackle the issues regarding Beaver Brook it is anticipated that the restoration effort will take time due to trial and error of specific practices involved in restoration efforts.

GPS Plotting

In order to understand the inventory of Japanese Knotweed residing along Beaver Brook, the researchers needed to plot GPS points of the invasive species. On September 26th,

2009, the researchers went out to the brook and plotted the specific locations of Japanese Knotweed. One researcher traversed the brook with a GPS device locating any points that were not accessible by foot. Some of these locations included the channelized parts of Beaver Brook. Figure 9 shows the researcher in the brook taking GPS coordinates of Japanese Knotweed. As some points of the brook were very deep, the researchers had to go out a second time with a canoe in order to get all of the locations of Japanese Knotweed.

Figure 9 *Researcher taking GPS coordinates of Japanese Knotweed* (Source: Authors)

Once all coordinates were collected, the researchers plotted the points in ArcGIS, a geographic information systems mapping program (Figure 10). The green squares represent the clusters of Japanese Knotweed found along the brook. The data that were collected as

fieldwork during this study was an essential component of the entire research. The survey collection, pH level testing, and plotting of the GPS coordinates of Japanese Knotweed all help draw conclusions on the future plans of the restoration process.

When analyzing the locations of Japanese Knotweed in Figure 10, it is noticed that the plants are not evenly dispersed along Beaver Brook. As seen in the map, the knotweed is located in clusters along the entire length of the brook; however, it is most prevalent along the portion located south of Roxbury Street. To be more specific, the greatest cluster of Japanese Knotweed extends from the banks of Carpenter Field to the southern property line of Mr. Randy Fowler's property on Baker Street. This could be due to free reign of plentiful water and resources. When interpreting the map, the symbols for Japanese knotweed seem to overlap each other, especially in the stretch of knotweed from Carpenter Field to Mr. Fowler's property on the southern end of the map. The overlapping occurs because in these sections, the knotweed is located on both sides of the brook. Besides overlapping of points, in some stretches, there are no points plotted. This indicates there is no Japanese Knotweed in that location. Some stretches of Beaver Brook do not support the growth of the plant because of commercial and residential channelization. Portions of Beaver Brook are channelized in both commercial and residential areas, which destroy the banks that are needed for the plant to grow. In order to control or eradicate Japanese Knotweed, some form of removal needs to take place. In some sections of the brook manual pulling of the plant would work best, but in other sections this would be too painstaking of a task. To fully eradicate the clusters of knotweed, a biodegradable herbicide would be the most efficient and successful task. If both of these forms of removal were used, eradication would be very successful.

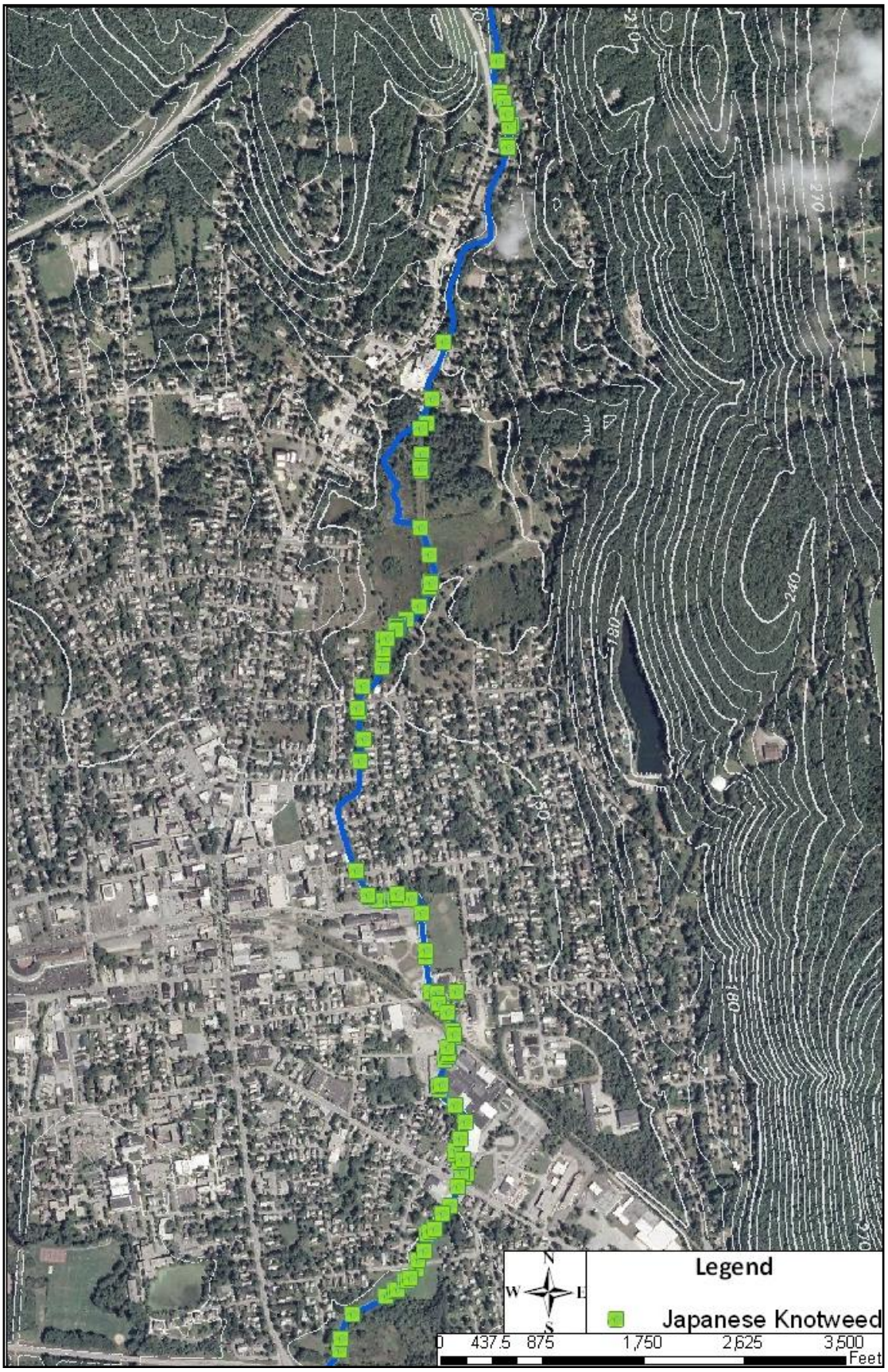


Figure 10 *Japanese Knotweed along Beaver Brook*

Three Proposed Property Parcels

The City of Keene has chosen three specific property parcels to focus on in East Keene: Woodlawn Cemetery; Carpenter Field; and a parcel of land owned by Mr. Randy Fowler located on Baker Street. The relative locations of the three primary restoration sites are displayed in Figure 11. Mr. Fowler's property fronts Baker Street, Carpenter Field fronts Carpenter Street and the Woodlawn Cemetery fronts Beaver Street and North Lincoln Street. These locations warrant special attention as they are the only three locations along Beaver Brook where the public has access to the water. Collectively these parcels total 93.46 acres, the majority of the acreage belonging to the Woodlawn Cemetery parcel.

Located south of Woodlawn Cemetery and north of Carpenter Field, resides a residential neighborhood that acts as a buffer between the two parcels. South of Carpenter Field, an industrial area along with a residential neighborhood separating Carpenter Field from Mr. Fowler's property. To The east of Woodlawn Cemetery lays a heavily wooded area, this is the only restoration parcel that abuts a forest with the exception of the small wooded area in the southern section of Mr. Fowler's Property (directly south of this small wooded area is Route 101 followed by commercial areas).

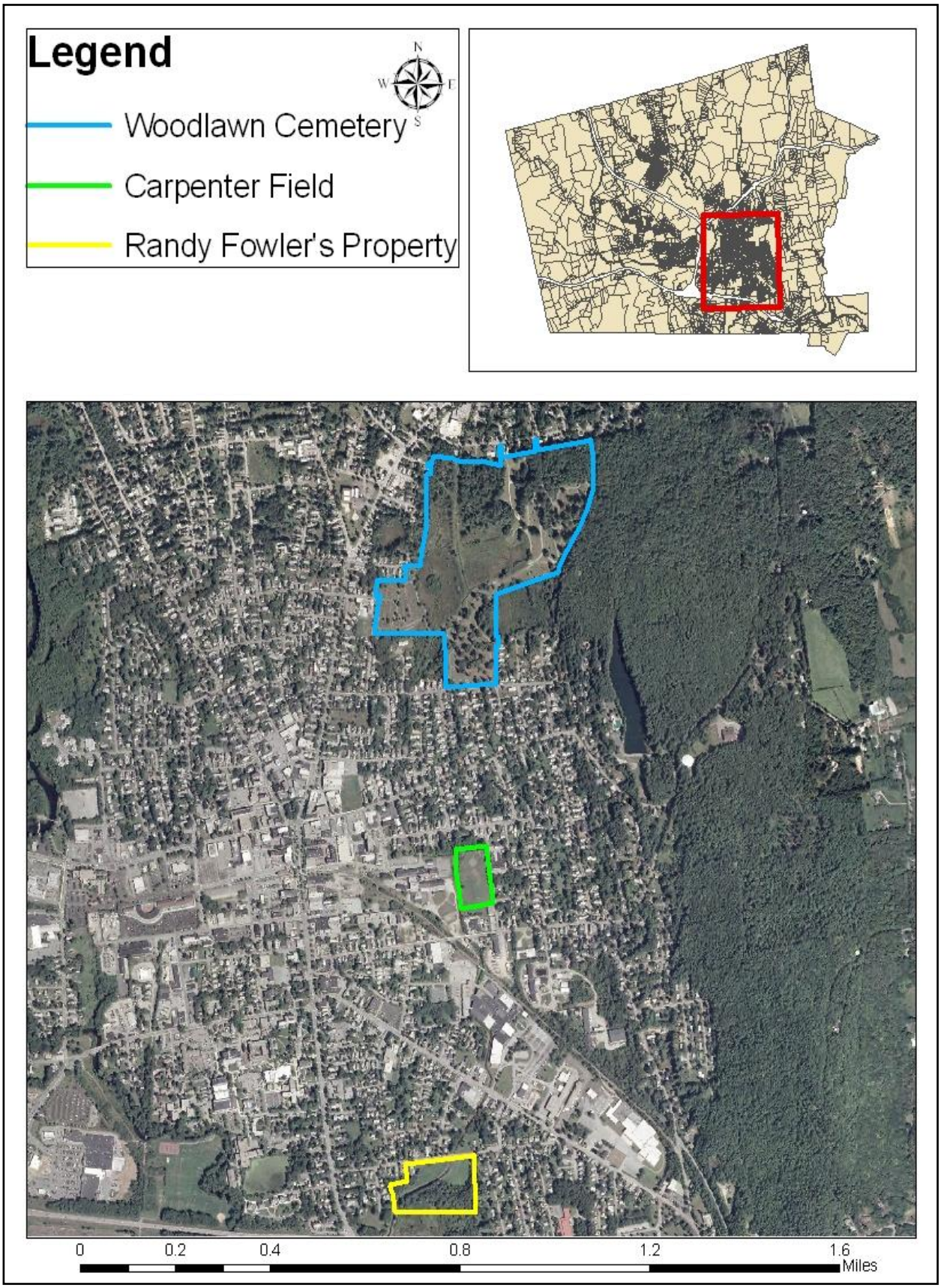


Figure 11 *Locations of three primary restoration sites in Keene, New Hampshire.*

Woodlawn Cemetery

Encompassed within 80 acres of land Woodlawn Cemetery is the northern most and largest parcel of property included in the restoration plan (Figure 12). The Woodlawn Cemetery parcel is home to an abundant amount of wildlife and provides a serene atmosphere to the many cyclists and runner/walkers who navigate their way through its winding roads. As the Brook meanders through this parcel it is plagued with Japanese Knotweed. Consequently, the reintroduction of different types of native bushes and trees has been implemented along the outskirts of the banks of the brook, as seen in Figures 13 and 14. The new bushes do not have any effect on the brook and other plants as of right now, but as the time passes, the plants and trees grow, providing the brook with shade. The bushes will also provide competition for the knotweed which will slow the spread. The planting of the bushes and tree will be a tremendous asset to the health of the brook and wildlife population.

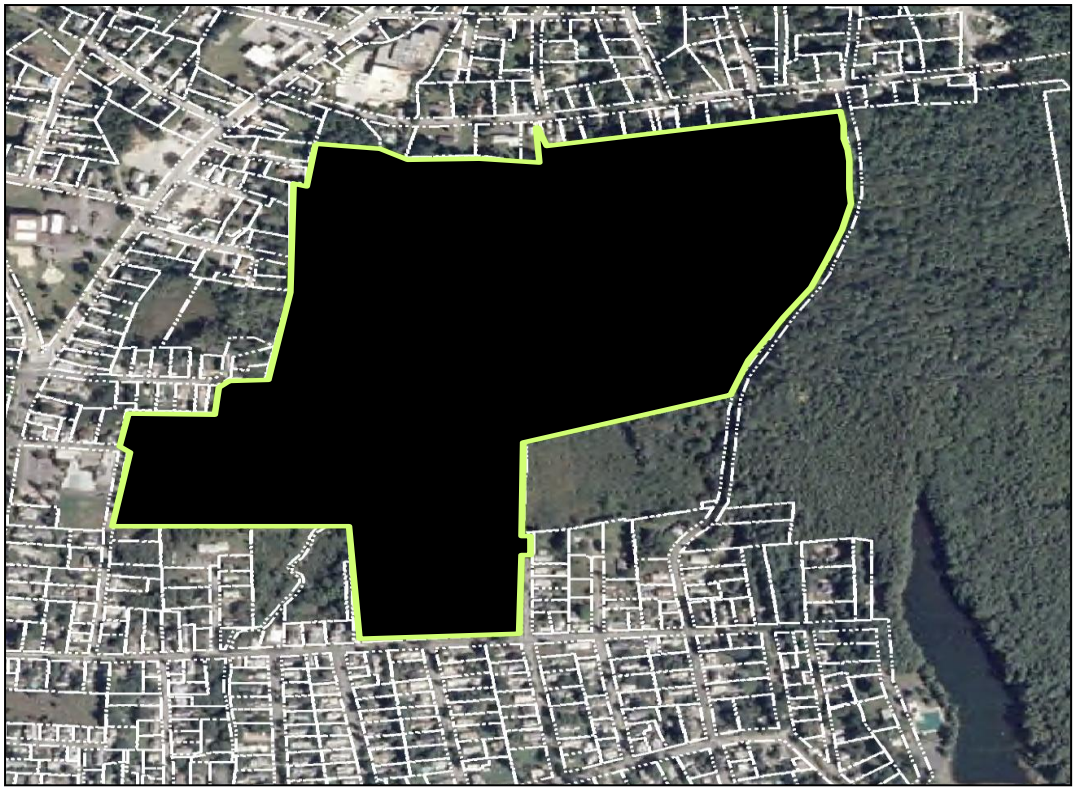


Figure 12 *Woodlawn Cemetery*

Figure 13 *Native plants planted along Beaver Brook* (Source: Swope)

Figure 14 *Native tree planted along the brook* (Source: Swope)

Carpenter Field

Lying south of the Woodlawn Cemetery property parcel resides the 4.96 acres of land known as Carpenter Field (Figure 15). The field itself serves as a large playing area where many different sports activities can take place. Local sports teams migrate here to conduct practices when school or local facilities are occupied. The field is also ideal for residents walking or training their dogs. This parcel, like that of Woodlawn Cemetery, is serene and lush in the summer months, but tends to be more of an oasis because of its location in the middle of residential and industrial areas. Carpenter Field is also home to playground equipment and a softball field, which allows insight to who is actually utilizing this area.

Figure 15 *Carpenter Field*

The riparian ecosystem of Beaver Brook in Carpenter Field is being invaded by the Japanese Knotweed as seen in Figure 16. From analyzing the photo it is noticed that the

knotweed grows extensive in this stretch of the brook. Both sides of the banks are completely invaded by the plant. The objective of restoring the aquatic riparian habitat is to remove or eradicate all of the Japanese Knotweed, and to plant native species, grown in New England, in the areas where the knotweed used to be after eradication takes place (City of Keene 2009f). For example, trees like the sycamore and sugar maple are going to be planted in order to shade the brook (City of Keene 2009g). This will cool the river for a healthy fish population. Other plant species that are going to be implemented along the brook are berry bushes such as high bush blueberry and winterberry holly. These bushes provide birds and wild animals with a source of food. The last types of plants that are going to be implemented along the brook are plants that cover the ground. These perennial ground cover plants include ferns and wildflowers (City of Keene 2009g). The purpose of the ground cover is to provide cover for small animals and they are aesthetically pleasing for humans.

Figure 16 *Japanese Knotweed in Carpenter Field.*

Randy Fowler's Property

The 8.5 acres residing on Baker Street in Southeast Keene make up the third and final property parcel belong to Mr. Randy Fowler, Figure 17. Mr. Fowler allows the public to utilize his property on a daily basis. Activities that take place on Mr. Fowler's property include; people walking their dogs, gardening, and varied sports such as Frisbee. Although he is not partial to the public conducting activities on the west side of the brook (where his home is located), he graciously allows the public to utilize the east side of the brook.

Figure 17 *Randy Fowler's property*

Continuing with native plantings the next step taken was the planting of four hybrid elm trees by the City of Keene on Baker Street as seen in Figure 18. This particular hybrid elm is immune to the ever problematic Dutch Elm Disease. The trees were originally scheduled to be

planted along the road on city owned property, but the locations of underground pipes required the movement of two of the trees. The city owns land a distance of five feet back from the road and this movement meant that the two trees will be moved farther back from the road and placed on Randy Fowler's property.

Figure 18 *Four hybrid elm trees along Baker Street* (Source: Authors)

The City of Keene had to obtain permission from Mr. Fowler to plant the elm trees, as they were now going to be on his property. Mr. Fowler gave the city permission to plant the trees with the understanding that the city will maintain the trees. The purposes, in part, of the four elm trees, are to shade the stretch of Beaver Brook that runs under Baker Street and through Mr. Fowler's property. The shade will act as a cooling agent to the water so fish populations, specifically trout can thrive. The trees are also aesthetically pleasing to the neighborhood. Another measure the City of Keene is implementing to the brook on Randy

Fowler's property is the mowing along the banks of the brook. This stretch of land as seen here in Figure 19 is one of the only places along the brook that can be mowed by the city. Most of Beaver Brook runs through residentially concentrated private property or has been channelized, so mowing is not practical except in a few locations, such as Woodlawn Cemetery, Carpenter Field and Mr. Fowler's property. Mr. Fowler favors the mowing of the banks on his property, and states that he "would like to see the mowing of the banks done more often" because it reduces the height of the Japanese Knotweed (Figure 20). On his property, there also are blackberry bushes, which Mr. Fowler lets the community pick if wanted. He also states that he would like to see a bridge put up so individuals are able to cross the brook farther down his land.

Figure 19 *Parcel of land owned by Randy Fowler who is standing to the far right in the photograph* (Source: Authors)

Figure 20 *Mowing of Baker Street*

pH Testing Analysis

The researchers also went out to collect pH level data on eight randomized outfalls along Beaver Brook. Shown in Figure 21 is one of the researchers dipping the pH test strips into one of the outfalls located off Marlboro Street. The outfalls are frequently spread out along the brook. One of the outfalls that were tested is displayed in Figure 22. This outfall can be found along Randy Fowler's property on Baker Street.

Figure 21 *Testing pH levels in Beaver Brook*

Figure 22 *Outfalls along Beaver Brook*

The map in Figure 23 shows the eight outfalls where pH levels were tested. At each of the outfall locations a group member had to get down into the water and put the test strip directly into the water and hold it there for five seconds. Immediately after the test was removed from the water it needed to be compared to the legend that was given with the test strips to define the pH level.

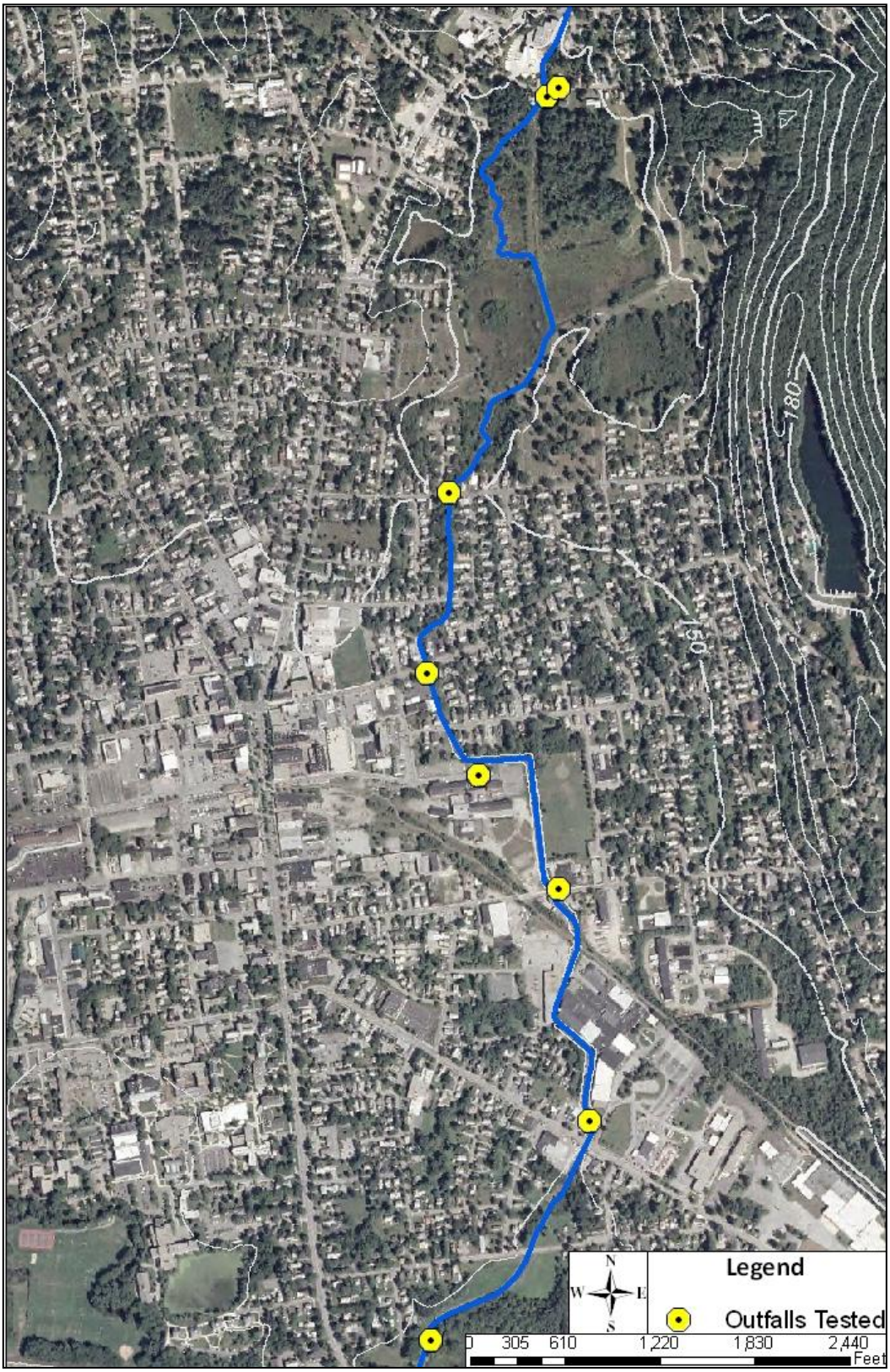


Figure 23 *Outfalls where pH levels were tested*

Figure 24 is a replica of the pH level test strips. As pH level values decrease, the degree of acidity rises. Conversely as pH level values increase the degree of alkalinity rises. It illustrates the fifteen level pH scale measuring the alkalinity and the acidity of water, with zero being the most acidic and fourteen being the most alkaline, seven is neutral. When pH values decrease or increase to the next level (example: a pH change from 7.0 to 6.0 or 5.0 to 6.0) the solution is ten times as acidic or basic then the previous level. As pH values decrease aquatic life begins to expire. Rainbow Trout begin to die at a pH of 6.0. Frog eggs, tadpoles, crayfish, and mayflies die at a pH of 5.5 and all fish die off at a pH of 4.2 (EPA 2009).

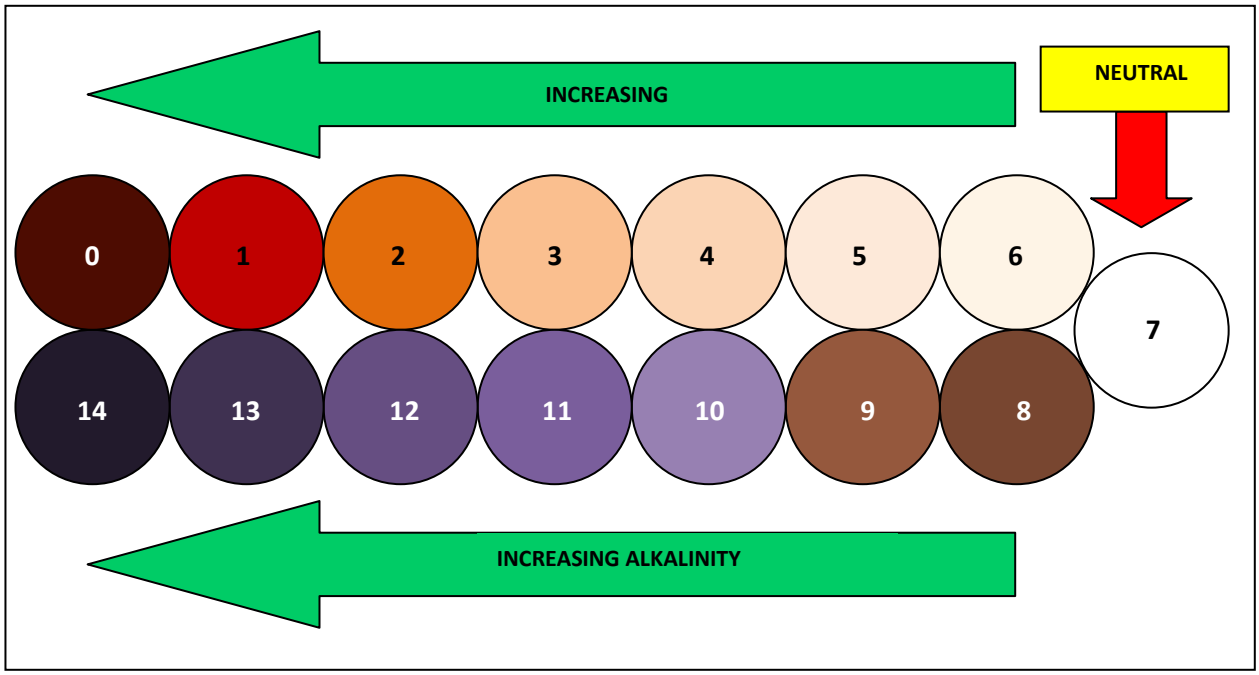
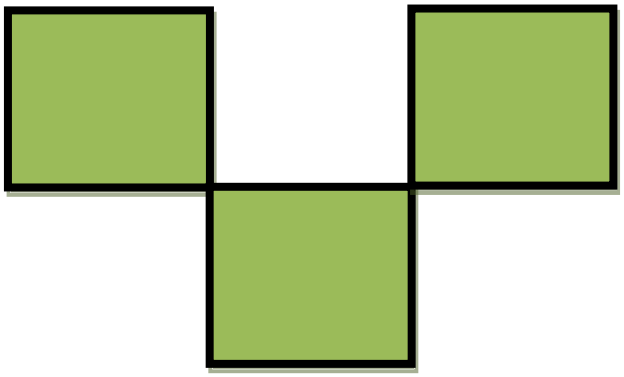


Figure 24 *pH levels scale*

High waters may have diluted the true pH value of the brook while sampling for pH values along outfalls. The night before the pH levels were collected, a rain storm had taken place which also could have skewed the pH results. Since all of the pH tests read of 5.0, it could also be possible that use of test strips was not overly accurate. Channelization made it difficult

to obtain pH values in certain areas along the brook due to fences and the height of the cement channel.

Through primary data collection and analysis, it is possible to foresee that the restoration effort taking place in Beaver Brook will more than likely take a sufficient amount of time to complete. Problems facing the brook that are being addressed include; water quality value (as to maintain and restore aquatic life), the eradication of riparian invasive species (Japanese Knotweed being the most prevalent), and the education of the residents of Keene on riparian ecosystems. Through the interview (Mr. Randy Fowler), mapping of property parcels, pH level testing, and plotting of Japanese Knotweed coordinates though GPS, data will be able to be analyzed by city officials to conduct decisions on further plans of restoration for Beaver Brook. The primary and secondary data research conducted in this study was designed for use by the City of Keene to forward the restoration effort.



Chapter 5:

Survey Methodology and Analysis

The methodology for the survey component of this project is shown in Figure 25. This figure starts at the base of the pyramid with the first step in the research process, and then works its way up the pyramid to the different steps followed. Using the data collected throughout the research project, conclusions are formed to either reject or fail to reject the null hypotheses. The null hypothesis states that residents of Keene who are homeowners and renters have the same level of awareness of invasive species residing along Beaver Brook. Primary data, collected by surveying members of the community to gain a better understanding of residents' attitudes and opinions on Beaver Brook, then ensued.

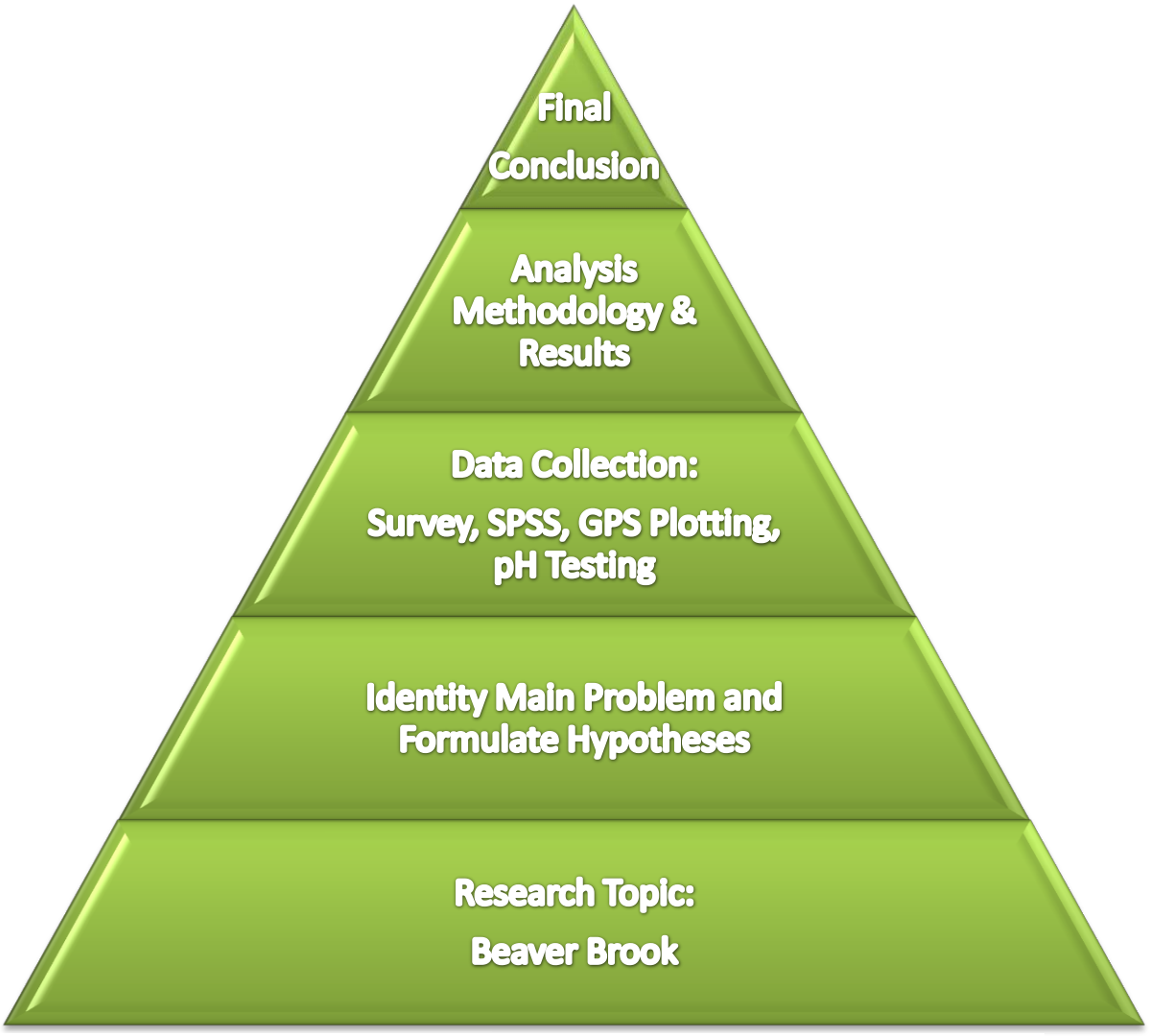


Figure 25 *Survey Research Methodology*

Survey Methodology

Primary data collection was produced and distributed on three different occasions. The first distribution took place on October 3rd, 2009, at the local "Source to Sea" river cleanup hosted by Mr. Eric Swope of the City of Keene. At the Source to Sea cleanup, surveys were completed by volunteers cleaning litter out of the brook (Figure 26). The second distribution took place on October 13th, 2009, at a meeting of the Southeast Keene Neighborhood group. The final data collection of the surveys took place on October 31st, 2009, where the surveys were dispersed by going door- to-door to households around the Baker Street field. From these three data collection times a total of 54 completed surveys were received.

Figure 26 *Distributing surveys*

A majority of the residents approached were more than willing to take part in giving personal input on the restoration plan of the brook. Some residents were not fully aware of the ongoing restoration efforts, and seemed eager to learn more. Many of the homes surveyed were not directly in the floodplain, but were directly affected by the 2005 flooding of the brook (Figure 27). Figure 28 shows the surveyed areas when door-to-door data were gathered. The researchers started out going west on Baker Street, then worked towards Boston Place. From Boston Place the researchers backtracked down Baker Street towards Adams Street. After Adams Street a circle was made to approach residents on Monadnock Street, Monadnock Court, Kelleher Street, and then back to Baker Street. This block was selected as it is directly adjacent to the property owned by Mr. Randy Fowler. The residents living in this neighborhood were surveyed because they are most likely to be aware of and to utilize Randy Fowler's property and are able to provide a lot of insight and ideas.

Figure 27 *Keene Flood 2005* (Source: Google Images)

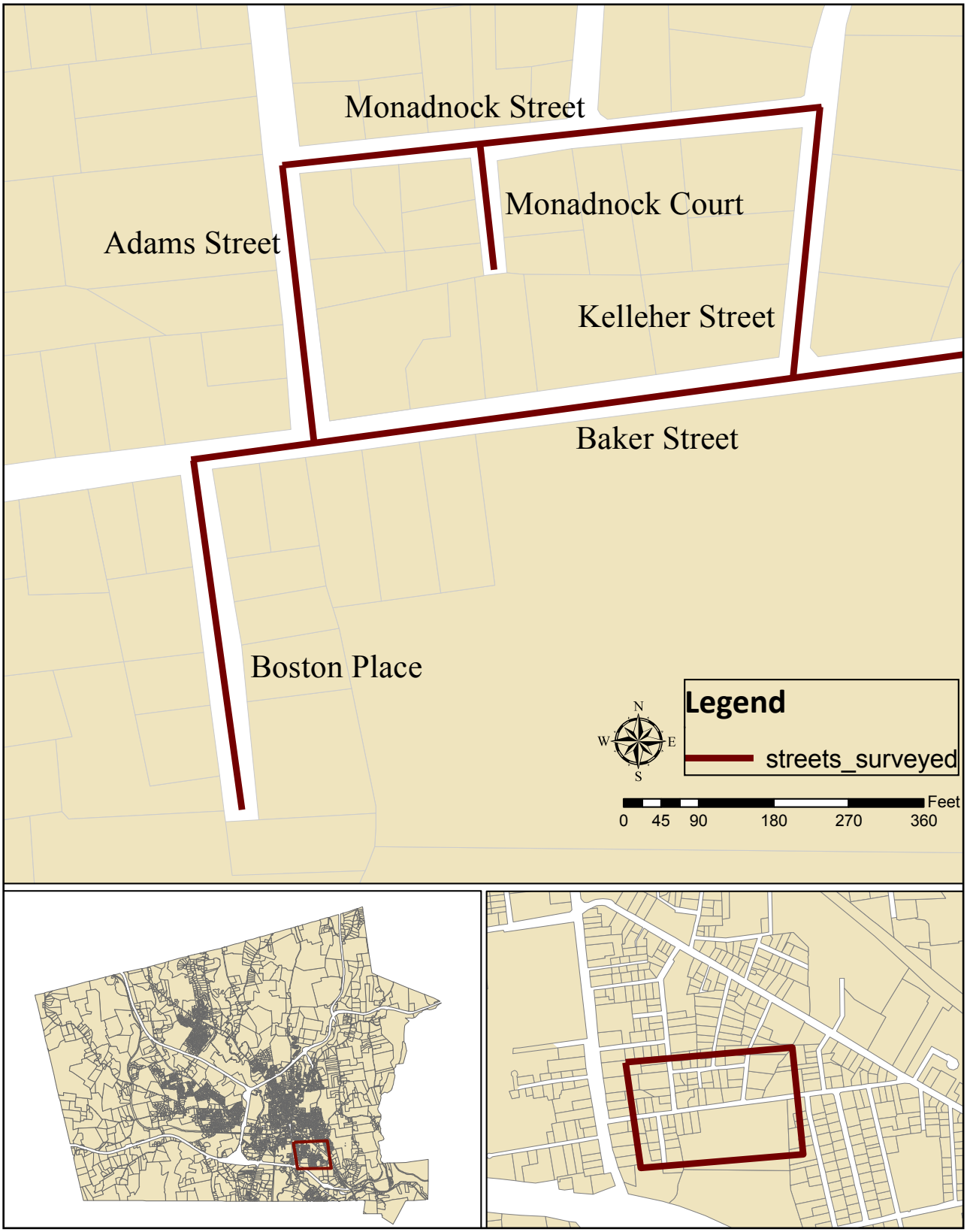


Figure 28 *Relative locations of houses surveyed*

The survey is broken down into a one page, double sided form which asks a wide variety of questions to obtain data on residents' personal opinions and knowledge of Beaver Brook (Appendix A). Basic questions are asked in the beginning of the survey to attain background of the respondents. These questions include; gender, age, general area of residency, enrollment at KSC, and whether they own a home or rent. Through these insights, respondents were divided into categories such as age brackets, renter or homeowner, male or female, or residing in or out of the Beaver Brook floodplain. The next series of questions are aimed at gaining awareness levels of respondents regarding invasive species, river cleanups, restoration efforts, and information on respondent's familiarization of Beaver Brook. By tallying the answers to these questions, data were drawn from the survey identifying respondents who were more or less aware of issues asked.

The reverse side of the survey asks respondents to rate their level of agreement to a series of statements regarding; flooding, native species plantings, aesthetics, water quality and financial support of Beaver Brook. Through these replies, data were gained to evaluate toward which topics respondents directed their level and strength of agreement. The findings were then run through a computer program used for statistical analysis, called SPSS, specifically using an ANOVA. This test is used for an analysis of variances between different groups to identify which types of respondents replied to what levels of agreement, and to find a statistical significance amongst the different categories. The final section of the survey asked respondents to identify the "best thing" and "worst thing" about Beaver Brook. These questions are designed to generate answers regarding respondents' thoughts of Beaver Brook to rank responses discovering the positive and off-putting traits of the brook. Through the

multiple results of this survey, statistical data were able to depict the types of respondents who are conscious of Beaver Brook, aware of issues regarding restoration, and positions on concerns surrounding the brook.

Survey Results

The number one "best thing" respondents seem to enjoy about the brook is that it is a scenic location that local residents enjoy visiting. There is also a wide variety of wildlife in and around the brook that survey respondents feel is important to the brook. Several residents enjoy using areas surrounding the Beaver Brook for outdoor activities, primarily along the Carpenter Field parcel. A few flower gardens and plantings have been put in along Randy Fowler's Property on Baker Street and along Beaver Brook in the Woodlawn Cemetery. However, survey respondents ranked flower gardens as the fifth best aspect of Beaver Brook. Therefore, it would be beneficial to the brook if more flower gardens and shrubbery were planted along the Beaver Brook.

Even though, flood control is not a focus on the restoration of Beaver Brook, this problem was found to be the "worst thing" about the brook. Respondents also feel that the heavy amounts of pollution and trash along Beaver Brook, takes away from the brooks scenic landscape. Surprisingly, the overgrowth of plants and invasive species, which is the primary focus of this study, was found to be the fourth "worst thing" about Beaver Brook. Therefore, educating the public on invasive species would be beneficial to promote the problems of these native plants. Table 1 shows the breakdown of the five best and worst things about Beaver Brook.

Table 1 *Top five best and worst things about Beaver Brook*

Best	Worst
1. Scenic	**1. Flooding**
2. Wildlife	**2. Pollution**
3. Outdoor activities	**3. Trash**
4. Social atmosphere	**4. Overgrowth of plants/Invasive species**
5. Flower gardens	**5. Off road vehicles**

The comments that residents provided about benefiting the brook were insightful in the research of this project. One resident suggested that an "Adopt a Piece of Beaver Brook" program be put into effect. This would be similar to adopt a highway program that many states in the United States are using to help keep the highways clean. This program would enable residents to adopt a portion of Beaver Brook that they would be responsible for maintaining. Another idea introduced was educating members of the community on the issues that surround Beaver Brook, including control methods of Japanese Knotweed. A large majority of the survey respondents stated that significant efforts need to put into place by both the members of the community and also city representatives. An idea of not being able to build buildings along the Beaver Brook floodplain was stated by one survey respondent. This idea touched on the fact that the City of Keene needs to protect the pieces of nature the city has, and that the usage of land could be made more efficient.

Of the 54 residents surveyed, a slight majority were homeowners, and a substantially higher percentage of respondents were male (Figure 29 and Figure 30). Significant more than half of the surveyed population disclosed that they were not aware of invasive species residing

along Beaver Brook (Figure 31). An additional 35 percent of the surveyed population said they were only somewhat aware of invasive species.

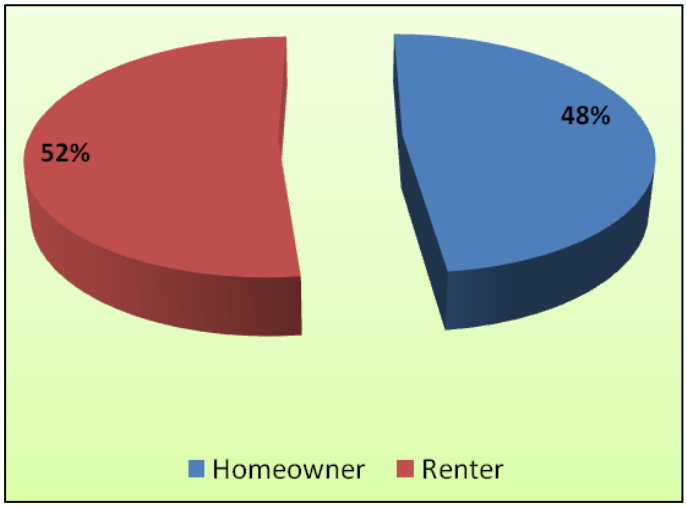


Figure 29 *Homeowner versus renter*

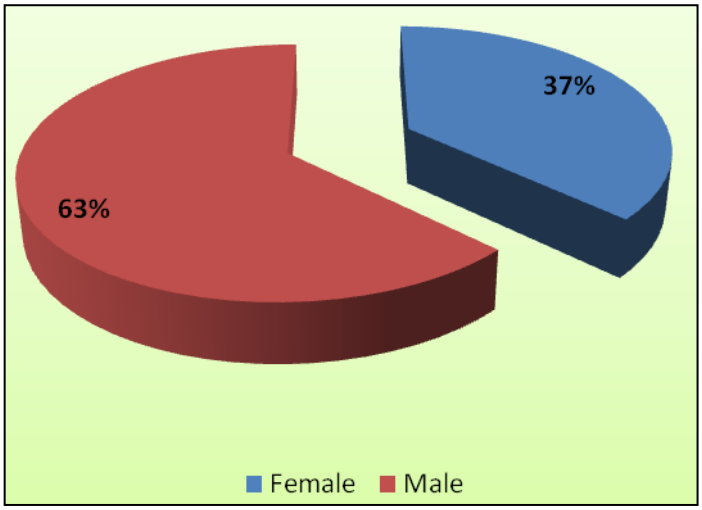


Figure 30 *Sex of survey respondents*

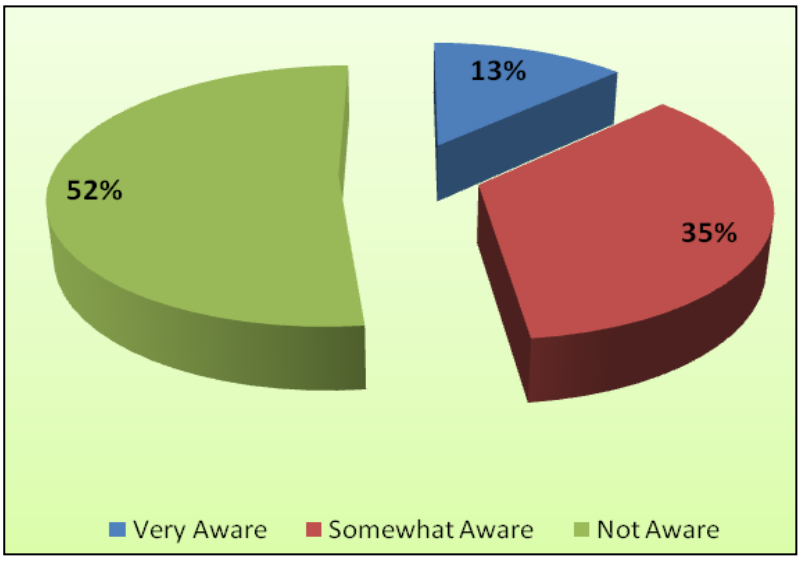


Figure 31 *Survey respondents awareness of invasive species*

Of the 54 residents of Keene surveyed exactly half were between the ages of 18 and 24 (Figure 32). The reasoning behind this statistic is that the locations where the surveys were distributed are all located within one mile of the college, in and around the Beaver Brook floodplain. Results of the survey population closely resemble the population pyramid of the

City of Keene. In relationship with the population pyramid a considerable amount of Keene's residents are located in the younger age brackets.

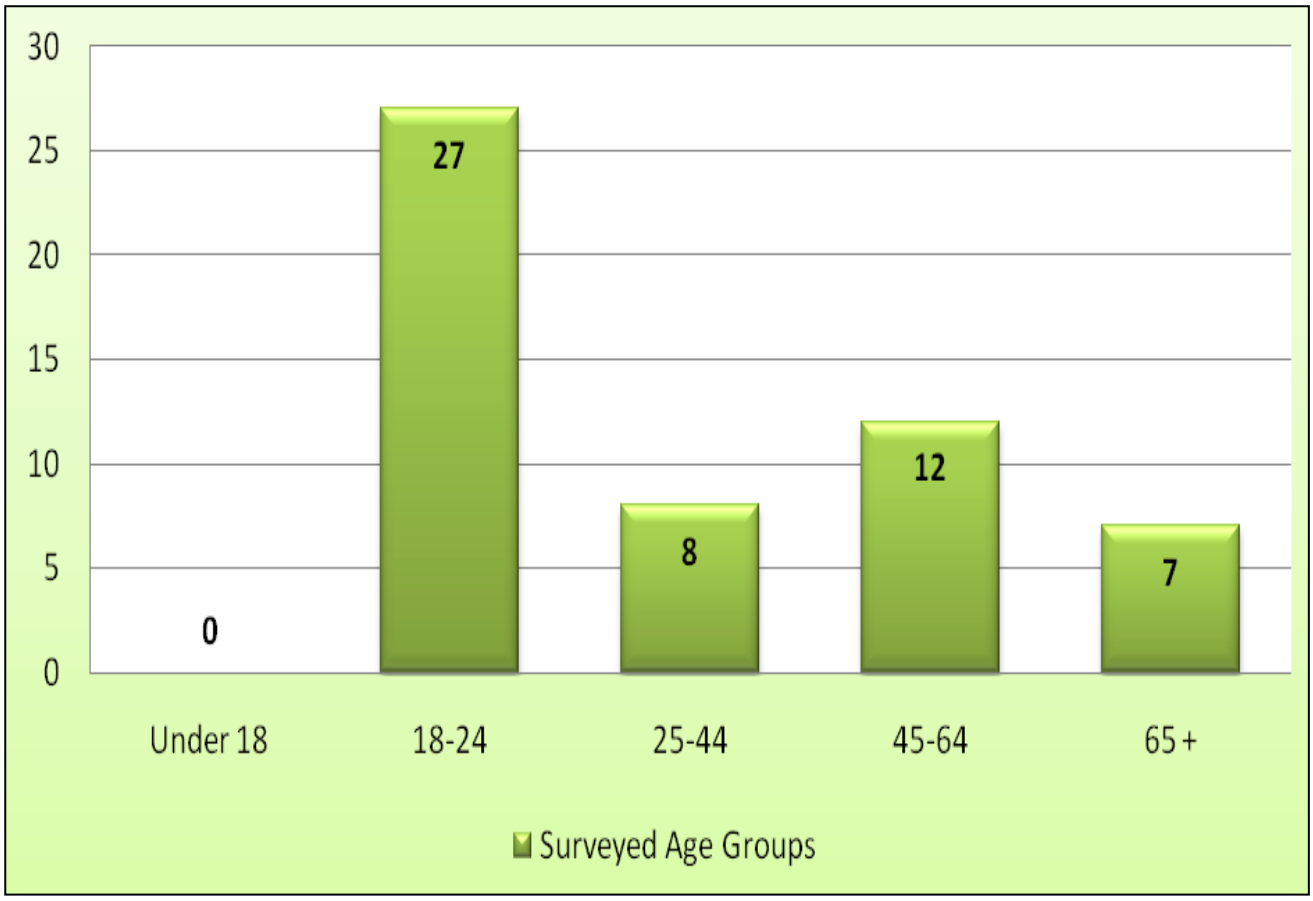


Figure 32 *Ages of residents surveyed*

The surveyed respondents were broken down into student and non students, as displayed in Figure 33, with equal amounts of respondents currently enrolled at Keene State College and those not currently enrolled in the college. A total of eight respondents did not respond to this question on the survey. This is considered a limitation, data cannot be revealed on whether or not those eight respondents are college students or not. Since the breakdown of students and non students is equal, a balanced amount of respondents took this survey. Data

from various different members of the community gives broad variety of responses and attitudes towards Beaver Brook.

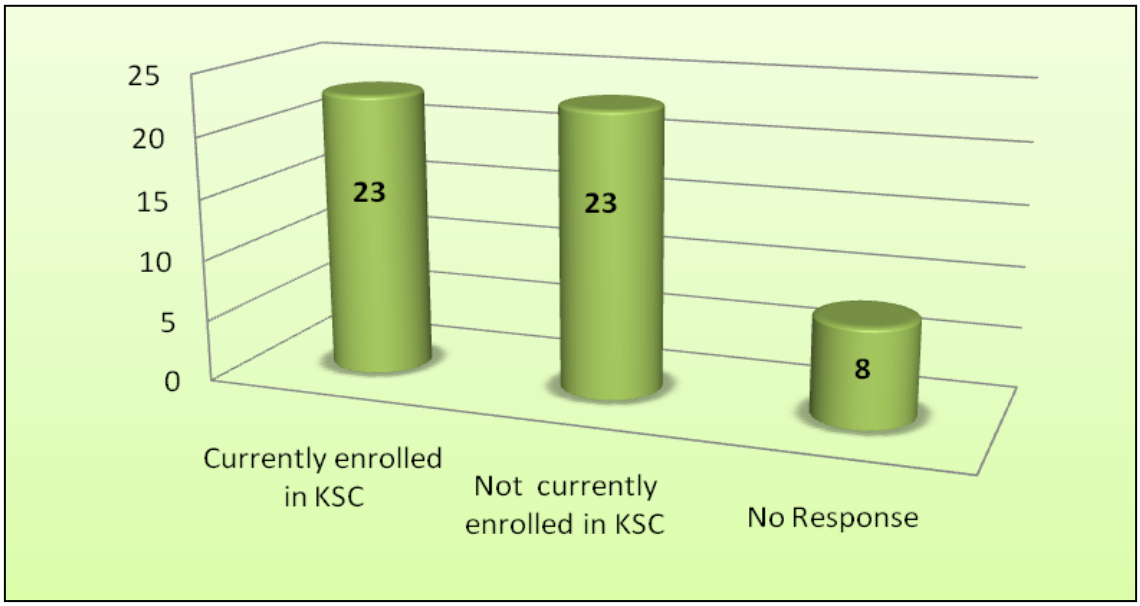


Figure 33 *Students versus non students surveyed*

Statistical Analysis

Running data gathered from surveys though the program SPSS helps to define areas of significant differences, relationships between data, and tests hypotheses. The original data collected in the survey provides numerous values for statistical testing (survey found in Appendix A). Through an Independent Samples t-test ran in SPSS, (Table 2), shown are significant differences between homeowners and renters residing in and around the Beaver Brook floodplain. Five out of six categories, except that regarding native species plantings, were found to be significantly different, with all possessing a value of 0.05 or less. This test reveals that homeowners dwelling in and around Beaver Brook are more concerned and invested in their neighborhood than are renters. Of the five categories that tested significant,

all were well under the 0.05 significance level. The native species plantings category only missed significance level by .057.

Table 2 *SPSS Independent samples t-test*

Issue	Mean	Significance (2-tailed)
Flooding		
Renter	1.96	.039 *
Homeowner	1.46	
Native Plantings		
Renter	1.92	.107
Homeowner	1.57	
Aesthetics		
Renter	1.89	.001 *
Homeowner	1.26	
Eradication of Invasive Species		
Renter	2.14	.014 *
Homeowner	1.53	
Water Quality		
Renter	1.75	.000 *
Homeowner	1.11	
Financial Support		
Renter	3.26	.003 *
Homeowner	2.30	

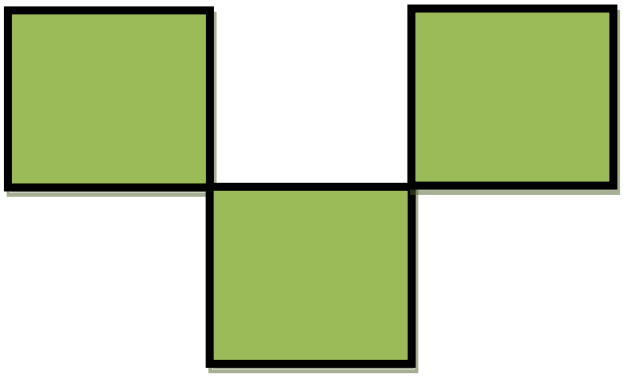
*Significant at the 0.05 level (2-tailed)

Statistics also demonstrate that there is a significant difference between age groups regarding the level of awareness of invasive species residing along Beaver Brook. Through a Post Hoc test run through ANOVA in SPSS, data reveal that persons in the age bracket 45 to 64 are significantly more aware of invasives than those persons in age bracket 18 to 24. The null

hypothesis states that residents of Keene who are homeowners have the same level of awareness of invasive species residing along Beaver Brook as do renters. Rejection of the null hypothesis is the action taken when the significance is less than .05, thus disproving the null hypothesis. This may be due to the persons residing in age bracket 45 to 64 are mostly homeowners who have lived in the Beaver Brook area for several years. An overwhelming majority of renters were college students falling into the age bracket category of 18 to 24. There were no homeowners in the age bracket 18 to 24. Of the 28 renters surveyed 20 were not aware of invasive plant species residing along Beaver Brook, seven were somewhat aware and only one were highly aware. Of the 26 homeowners surveyed nine were not aware of invasive plant species residing along Beaver Brook, eleven were somewhat aware and six were very aware. This data suggests that homeowners may be more knowledgeable about issues within the neighborhood regarding efforts towards local projects then those of renters who are mostly composed of college students.

Through the analysis of surveys, expressed is that the homeowner in the City of Keene is overall more aware and more concerned with the restoration efforts of Beaver Brook then the renter. The best thing about Beaver Brook was said to be the scenery and aesthetics along the brook. Although most could agree with the best aspect about the brook, many included flooding and pollution as the worst aspects about the brook. Though the restoration effort does not directly encompass flooding it is a major concern of a greater part of respondents within the Southeast Keene area. Although homeowners were more aware of the invasive plant Japanese Knotweed than renters, the overall awareness of Japanese Knotweed was low. This justifies the need of more education in the community on issues dealing with river

restoration such as being able to identify invasive species. Remarks respondents wrote (referring to the "Adopt a Piece of Beaver Brook," comment) on the survey provided researchers with further insight into ideas the community had been pondering about restoration efforts that may not have been contemplated before by the City of Keene. With suggestions as this, the community of Keene remains concerned and dedicated to the perseverance of the restoration effort.



Chapter 6:

Conclusions

Concluding Statements

Located in the southwest corner of New Hampshire, the City of Keene is home to 22,407 residents with 5,282 college students. Established in 1753 and named after a British minister to Spain, Sir Benjamin Keene, the City of Keene holds a long standing civic and environmental heritage. With its various environmental programs, the city exercises 'green' ethos in many aspects of Keene. KSC supports Keene by lending a helping hand and engaging in just as 'green' programs as the city itself. Both the City of Keene and KSC have programs dedicated to reducing admissions, utilizing of environmentally friendly products, educating about environmental issues, and instituting groups to delineate environmentally friendly action. These groups include The City of Keene Green Team and President's Council for a Sustainable Future. Backing the City of Keene is a populace largely devoted to the sustainability for the good of the public as a whole. With the formation of green friendly programs and the fortitude to pursue such programs, the City of Keene has developed a model for other municipalities seeking sustainability to follow.

Located in southwestern New Hampshire, Beaver Brook begins at the Three Mile Reservoir in Gilsum, New Hampshire, and meanders its way through Keene before emptying into the Ashuelot River. Situated on the eastern side of Keene, Beaver Brook makes its way through various neighborhoods and residential areas where many animal species can be found. Some of these animals that make the Beaver Brook watershed their home are fish, beaver, birds, and deer. In addition to animal use, citizens of Keene also make Beaver Brook a source of recreation. Residents use the brook as a path to walk their dogs, while some children play near the water. A major attraction that brings residents to the banks of the brook is the Woodlawn

Cemetery and Carpenter Field. Many citizens take daily walks and jogs through this area which gives the brook a great deal of notice. Although Beaver Brook serves as a natural amenity, it is not without problems. Some of the major problems occurring in the brook are pollution, invasive species, flooding, and water quality. In this study, the problem of invasive species, specifically the invasive Japanese Knotweed was the main concern. Japanese Knotweed thrives in disturbed areas especially along riparian zones and is found in vast stretches along the brook. The knotweed does great damage to other native plants and the ecosystem. In this study, locations of the Japanese Knotweed were mapped so restoration efforts can get underway.

Through the findings of statistical analysis, data reveal significant levels in several different categories. The null hypothesis, stating that residents of Keene who are homeowners have the same level of awareness of invasive species residing along Beaver Brook as renters, was proved void. An Independent Sample t-test generated a significance of <0.05, thus rejecting the null hypothesis homeowners are more aware of invasive species residing along Beaver Brook than are renters. Statistical testing through ANOVA also found data to be significant at a level of <0.05 regarding age brackets and the level of awareness of invasive species residing along Beaver Brook. The test proves that respondents in age bracket 45 to 64 are significantly more aware of invasive species residing along Beaver Brook then those in age bracket 18-24. These statistical tests help to provide information regarding who is knowledgeable and who needs to be educated on environmental issues such as invasive species.

This study has located linkages between residents of the City of Keene and the restoration of Beaver Brook, concurrently providing education to the public regarding river

restoration and awareness of invasive species, Japanese Knotweed. The intent of this study is essentially to benefit the City of Keene and any other municipality attempting to restore aquatic riparian habitats and with educating the public on invasive species specifically, the following recommendations are advocated. The future of Beaver Brook is looking up, with the dedication of an environmentally knowledgeable community at the helm, the brook is in caring hands.

Education

Education is the key to success. In order for Beaver Brook to be recognized and supported, residents need to become aware of the local brook and the issues it faces. The only means by which residents of Keene will become aware of the ongoing problems facing Beaver Brook is if public education takes place. Many residents surveyed for this study did not know Beaver Brook even existed, never mind knowing that there are problems within the brook. As for the residents who knew of the brook, several could not locate where it resides. In order to maintain and restore the brook, many hands are needed, and without the knowledge of the residents, accomplishing the restoration of the brook may be problematic.

Adopting a piece of Beaver Brook

Providing local residents with the opportunity to adopt a portion of Beaver Brook may help make the members of the community more aware of the brook, as well as the many environmental and economic issues that come with Beaver Brook. This program would essentially help Beaver Brook's restoration plan, by providing a pool of volunteers to help with the restoration. Theoretically, residents of the City of Keene will be more apt to keep Beaver

Brook cleaner if they are personally invested in the restoration of the brook. Adopting a portion of Beaver Brook could be a great way to bring the community together and get many residents, and even outside community members, involved and aware of the problems rivers face such as Beaver Brook.

Eradication of Japanese Knotweed

Removal of Japanese Knotweed is a hard and tedious task. The main control measures include mowing of the infected area, cutting each individual stalk, herbicide application, manual pulling, and use of the *Gallerucella Beetle*. In order for Beaver Brook to return to its original state, some form of eradication needs to be put into effect. The best and most effective means of control is manual pulling the plant and application of an herbicide. If done correctly, these two means of control will have great success. Manual pulling is an effective means of removal because even though it is labor intensive, there is a greater percentage of removing the whole plant, including its roots. All parts of the root need to be removed or the knotweed has a very high percentage of regenerating and growing or spreading. The application of an herbicide is also one of the more effective ways to eradicate Japanese Knotweed because applying herbicides kill the plant directly. The most effective way of doing this is to have one person cutting the stalk and the other injecting the herbicides. When applying herbicides, the appropriate chemical needs to be used. If the wrong herbicide is used, other vegetation in the area could be affected. These two means of control, although both labor extensive, are the best ways of controlling and eradicating Japanese Knotweed.

Future Research

In order to determine the effectiveness of Beaver Brook's restoration plan, future studies will need to be assessed. Following up on the restoration plan will potentially provide information regarding how the project has progressed over time. Future researchers can use GPS units to re-plot the locations of Japanese Knotweed along the brook. This information could be compared to the map of Japanese Knotweed generated for this study to determine if the amount of knotweed has decreased over time. Researchers could also test the pH levels of Beaver Brook in the eight locations that were initially tested in October of 2009. Future pH levels could be compared to the present results, to see if there is a difference in pH levels. Further conclusions and plans to continue with Beaver Brook's restoration would be able to be determined after these research processes are conducted and analyzed. These future studies would be compared to thus, a baseline analysis that has identified both the problems and prospects associated with the restoration of Beaver Brook.

References

Aberdeenshire Council. 2005. The Ythan Project. http://www.ythan.org.uk/ (last accessed November 2, 2009).

Benke, A.C. 1990. A Perspective on America's Vanishing Streams. *North American Benthological Society* 9(1): 77-88.

Bram, M.R., and J.N. McNair. Seed germinability and its seasonal onset of Japanese knotweed. *Weed Science* 57(6):759-767.

Brookes, A. (1988). *Channelized rivers: perspectives for environmental management*. Chichester, UK: Wiley.

City of Keene, New Hampshire. 2009a. Central Square One of the Top 10 Great Public Spaces. *City of Keene, New Hampshire.* http://www.ci.keene.nh.us/central-square-one-top-10-great-public-spaces (last accessed October 27, 2009).

City of Keene, New Hampshire. 2009b. Keene Green Team. *City of Keene, New Hampshire.* Available at http://www.ci.keene.nh.us/sustainability/keene-green-team (last accessed October 27, 2009).

City of Keene, New Hampshire. 2009c. Wood Stove Changeout Program. *City of Keene, New Hampshire.* http://www.ci.keene.nh.us/sustainability/woodstove- changeout (last accessed October 2009).

City of Keene, New Hampshire. 2009d. Keene Challenge. *City of Keene, New Hampshire.* Available at http://www.ci.keene.nh.us/sustainability/keene-challenge (last accessed October 27, 2009).

City of Keene, New Hampshire. 2009e. The Environmental Preferable Purchasing Program. *City of Keene, New Hampshire.* http://www.ci.keene.nh.us/sustainability/sustainable-procurement (last accessed October 27, 2009).

City of Keene, New Hampshire. 2009f. Beaver Brook Restoration. *City of Keene, New Hampshire.* http://www.ci.keene.nh.us/sustainability/beaver-brook-restoration (last accessed October 27, 2009).

City of Keene, New Hampshire. 2009g. Habitat Restoration. *City of Keene, New Hampshire.* http://www.ci.keene.nh.us/sustainability/beaver-brook-restoration/habitat-restoration (last accessed October 27, 2009).

City of Keene, New Hampshire. 2009h. Water Quality Testing. *City of Keene, New Hampshire.* http://www.ci.keene.nh.us/sustainability/beaver-brook-restoration/water-quality-testing (last accessed October 27, 2009).

Dassonville, N., S. Vanderhoeven, W. Gruber, P. Meerts. 2007. Invasion by *Fallopia japonica* increases topsoil mineral nutrient concentrations. *EcoScience* 14(2): 230-240.

Faust, R. 2001. Invasive Species and Agriculture Pest Management: What We Have Learned. *Agriculture Research.* 49 (11): 1-2.

Ford, S. 2004. Cut and inject herbicide control of Japanese knotweed *Fallopia japonica* at Rocky Valley, Cornwall, England. *Conservation Evidence* 1: 1-2.

Keene State College. 2009a. Sustainability. *Seeing Green: Sustainability at Keene State College.* Available at http://www.keene.edu/sustain/ (last accessed October 9, 2009).

Keene State College. 2009b. R.O.C.K.S. *R.O.C.K.S.* http://www.keene.edu/rocks/ (last accessed October 27, 2009).

Keene State College. 2009c. Sustainability. *Goals.* http://www.keene.edu/sustain/ goals.cfm (last accessed November 7, 2009).

Kendle, E.R. 1970. The Effects of Channelization in the Missouri River on Fish and Fish-Food Organisms. *Nebraska Game and Parks Commission*. http://digitalcommons.unl.edu/nebgamewhitepap/23/ (last accessed December 3, 2009).

Koebel, Joseph. 2006. An Historical Perspective on the Kissimmee River Restoration Project. *Restoration Ecology* 3(3): 149-159.

Lamprey River Advisory Committee. 2008. Japanese Knotweed. http://www.lampreyriver.org/ (last accessed November 8, 2009)

Lecerf, A., D. Patfield, A. Boiche, M. Riipinen, E. Chauvet, and M. Dobson. 2007. Stream ecosystems respond to riparian invasion by Japanese knotweed (*Fallopia japonica*). *Canadian Journal of Fisheries & Aquatic Sciences* 64 (9): 1273-1283.

Maurel, N., S. Salmon, J. Ponge, N. Machon, J. Moret, and A. Muratet. 2009. Does the invasive species *Reynoutria japonica* have an impact on soil and flora in urban wastelands? *Biological Invasions.*

Miller, S. 1992. When pollution runs wild. *National Wildlife* 30(1): 26.

New Hampshire Department of Environmental Science (NHDES). 2006. http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-09-08.pdf (last accessed 6 November, 2009).

New York City Department of Parks and Recreation. 2009. Restoration Projects. *Invasive Species Removal.*http://www.nycgovparks.org/sub_about/parks_divisions/nrg/bronx_river_epa/BxR_watersheds_wetlands_mapping/Wetlands_restorations/invasives_removal/invasives_removal.html (last accessed 10 November, 2009).

Pimental, D., Zuniga R., and D. Morrison. Protectyourwaters.org. Update on the environmental and economic costs associated with alien-invasive species in the United States. http://protectyourwaters.org/news/data/EconomicCosts_invasives.pdf (last accessed 28 August 2009.

Plant Conservation Alliance (PCA). 2009. Least Wanted. *Japanese Knotweed*. http://www.nps.gov/plants/alien/fact/pocu1.htm (last accessed 10 November, 2009).

Prokop, W. A. Assistant City Manager/Human Resources Director of the City of Keene, New Hampshire. 30 October, 2009. Personal Communication.

Proper, D. R. 1968. *"Upper Ashuelot" A History of Keene, New Hampshire.* A Narrative of Keene, New Hampshire 1732-1967. Kay Fox, 1-235. City of Keene, NH.

Roni, P., T.J. Beechie. R.E. Bilby, F.E. Leonetti, and G. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration In Pacific Northwest Watershed. *North American Journal of Fisheries Management* 22(1): 1-20.

Serrentino, P. 2003. Japanese Knotweed Inventory of Selected Tributaries of the Deerfield River. Deerfield River Watershed Association www.mass.gov/Eoeea/docs/eea/water/deerfield_knotweed.pdf (last accessed 3 December, 2009).

Stone, A.E., T.F. Peeper, J.P. Kelley. 2005. Efficacy and Acceptance of Herbicides Applied for Field Bindweed (*Convulvulus arvensis*) Control. *Weed Technology* 23(3): 148-153.

Tang, S. M. and D. R. Montgomery. 1995. *Environmental Management.* Riparian buffers and potentially unstable ground. 19: 741-749.

The Nature Conservancy. 2009. Impact of Invasive Species. *Invading Our Lands and Waters* http://www.nature.org/initiatives/invasivespecies/about/ (last accessed 10 November, 2009).

The Source for the Seacoast. 2009. Plant life threatens Lamprey River Watershed. 13 March.

Toth, L.A., S.L. Melvin, D.A. Arrington, J. Chamberlain. 1998. Hydrologic Manipulations of the Channelized Kissimmee River. *BioScience* 48(9): 757-764.

University of Florida. 2005. Plant Management in Florida Waters. *Kissimmee River Restoration.* http://aquat1.ifas.ufl.edu/guide/kissriverst.html (last accessed 10 November, 2009).

Urgenson, L. S. 2006. *Invasive Species in the Pacific Northwest*, ed. P. D. Boersma, S. H. Reichard, and A. N. Van Buren, 64-65. Seattle and London: University of Washington Press.

U.S. Census. 2008. Keene City New Hampshire. *Demographic Profiles*. Available at http://factfinder.census.gov/servlet/STTable? (last accessed 14, September 2009).

United States Department of Agriculture (USDA). 2009a. National Agriculture Library. http://www.Invasivespeciesinfo.gov/plants/knotweed.shtml (last accessed 4 October 2009).

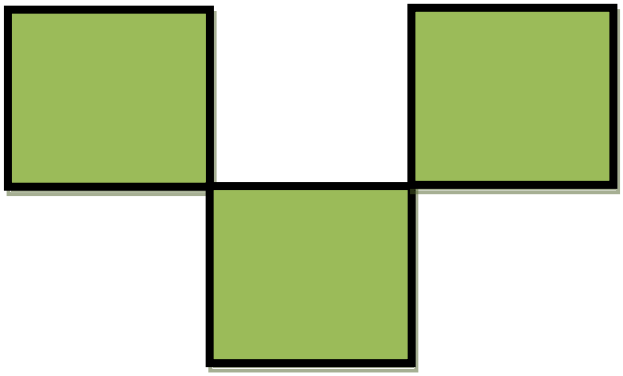
United States Department of Agriculture (USDA). 2009b. Plants Profile: Japanese Knotweed. http://plants.usda.gov/java/profile?symbol=Pocu6 (last accessed 11 November 2009).

United States Environmental Protection Agency (EPA). 2009. Agencies-Case Studies. *The Great American Wood Stove Changeout Program.* http://www.epa.gov/burnwise/casestudies.html (last accessed October 27, 2009).

Wang, Y., J. Ding, G. Zhang. 2008. Gallerucida bifasciata a potential biological control agent for Japanese Knotweed. *Biocontrol Science and Technology* 18(1): 59-74.

Weston, L.A., Barney, J.N., A., DiTommaso. 2005. A Review of the Biology and Ecology of Three Invasive Perennials in New York State: Japanese Knotweed (Polygonum cuspidatum), Mugwort (Artemisia vulgaris) and Pale Swallow-wort (Vincetoxicum rossicum). Plant and Soil *277(1): 53-69*

Winsor, A. Assistant Director Physical Plant. October 26, 2009. Personal Communication.



Appendices

Appendix A: Survey

Hello! We are Senior Seminar II students from the *Department of Geography* at *Keene State College.* Today's survey is to help conduct a capstone research project about the awareness of invasive species and the restoration of Beaver Brook in Keene, New Hampshire. Results from this study will be presented to the *Keene State College* faculty and students, as well as to representatives of the City of Keene. Your participation in this survey is greatly appreciated.

Gender:

___ Female

___Male

Age:

___ Under 18 years
___ 18 to 24 years
___ 25 to 44 years
___ 45 to 64 years
___ 65 years and above

Are you currently enrolled at Keene State College? ☐ Yes ☐ No

Please Circle: Renter Homeowner Campus Non-Applicable

Are you a resident of Keene, New Hampshire?

___ Yes. I live in the Beaver Brook floodplain
___ Yes. But I live outside the Beaver Brook floodplain
___ No. I Live outside of Keene Where (Town)? _____

Are you aware of the city of Keene's ongoing plan to restore Beaver Brook?

Yes _____ No _____

Have you participated in any river restoration efforts previously?

Yes _____ No _____

Do you plan on contributing to other river clean ups in the future?

Yes _____ No _____ Maybe _____

Are you aware of the invasive plant species residing along Beaver Brook?

☐ Very Aware ☐ Somewhat Aware ☐ Not Aware

How significant is the river restoration of Beaver Brook to you?

☐ Very Important ☐ Somewhat Important ☐ Not Important

What is your "level of awareness" of Beaver Brook?

☐ Highly Aware ☐ Moderately Aware ☐ Little / No Awareness

Please Turn Over →

Please check your level of agreement to the following statements:

	Strongly Agree	Somewhat Agree	No Opinion/ Don't Know	Somewhat Disagree	Strongly Disagree
1. Periodic flooding is a problem in Beaver Brook	☐	☐	☐	☐	☐
2. Reintegration of native species is important to Beaver Brook	☐	☐	☐	☐	☐
3. Aesthetics such as, landscapes and plantings is important to Beaver Brook	☐	☐	☐	☐	☐
4. Eradication of invasive species along the brook is important to Beaver Brook	☐	☐	☐	☐	☐
5. Improving water quality is important to Beaver Brook	☐	☐	☐	☐	☐
6. I would be willing to financially support the restoration of Beaver Brook	☐	☐	☐	☐	☐

Please rank the following reasons for Beaver Brook restoration in order of importance to you (One = least important and four = most important):

___ Aesthetics (landscapes, plantings, visually pleasing aspects)
___ Reintegration of native species (wildlife and plant)
___ Eradication of invasive species
___ Pollution and water quality

The *best* thing about Beaver Brook is…

The *worst* thing about Beaver Brook is…

Please provide any additional comments that would be beneficial. Thank you for your time and attention.

Appendix B: GPS Plots of Japanese Knotweed

OID	Field1	Latitude	Longtitude	Shape
0	1	**42.92621**	**-72.27025**	Point
1	2	**42.9263**	**-72.27017**	Point
2	3	**42.92631**	**-72.27032**	Point
3	4	**42.92656**	**-72.27041**	Point
4	5	**42.92676**	**-72.27052**	Point
5	6	**42.92683**	**-72.27053**	Point
6	7	**42.93973**	**-72.27181**	Point
7	8	**42.93941**	**-72.27224**	Point
8	9	**42.9393**	**-72.27248**	Point
9	10	**42.93926**	**-72.27257**	Point
10	11	**42.92403**	**-72.27174**	Point
11	12	**42.92208**	**-72.27422**	Point
12	13	**42.92237**	**-72.27419**	Point
13	14	**42.92293**	**-72.27382**	Point
14	15	**42.92339**	**-72.27276**	Point
15	16	**42.9235**	**-72.27247**	Point
16	17	**42.92354**	**-72.27236**	Point
17	18	**42.92374**	**-72.27213**	Point
18	19	**42.92374**	**-72.27204**	Point
19	20	**42.92382**	**-72.27196**	Point
20	21	**42.92424**	**-72.2717**	Point
21	22	**42.92445**	**-72.2715**	Point
22	23	**42.95144**	**-72.26909**	Point
23	24	**42.95194**	**-72.26932**	Point
24	25	**42.93277**	**-72.27311**	Point
25	26	**42.93275**	**-72.27311**	Point
26	27	**42.93278**	**-72.27267**	Point
27	28	**42.9328**	**-72.27258**	Point
28	29	**42.93276**	**-72.27255**	Point
29	30	**42.93279**	**-72.27247**	Point
30	31	**42.93278**	**-72.27244**	Point
31	32	**42.9328**	**-72.27204**	Point
32	33	**42.93056**	**-72.27136**	Point
33	34	**42.93059**	**-72.27135**	Point
34	35	**42.93055**	**-72.27117**	Point
35	36	**42.9306**	**-72.27054**	Point
36	37	**42.93142**	**-72.27152**	Point
37	38	**42.93156**	**-72.27155**	Point
38	39	**42.93246**	**-72.27168**	Point

39	40	**42.9329**	**-72.27246**	Point
40	41	**42.9392**	**-72.27253**	Point
41	42	**42.93917**	**-72.27259**	Point
42	43	**42.94463**	**-72.27147**	Point
43	44	**42.94598**	**-72.27111**	Point
44	45	**42.95116**	**-72.26895**	Point
45	46	**42.9511**	**-72.26901**	Point
46	47	**42.95068**	**-72.26911**	Point
47	48	**42.95062**	**-72.26905**	Point
48	50	**42.92486**	**-72.27142**	Point
49	51	**42.9249**	**-72.27136**	Point
50	52	**42.92501**	**-72.27119**	Point
51	53	**42.92551**	**-72.27069**	Point
52	54	**42.92533**	**-72.27092**	Point
53	55	**42.92599**	**-72.27046**	Point
54	56	**42.92663**	**-72.27027**	Point
55	57	**42.92751**	**-72.27021**	Point
56	58	**42.9271**	**-72.27039**	Point
57	59	**42.9279**	**-72.27054**	Point
58	60	**42.92827**	**-72.27105**	Point
59	61	**42.92836**	**-72.27109**	Point
60	62	**42.92835**	**-72.27108**	Point
61	63	**42.9284**	**-72.27103**	Point
62	64	**42.92897**	**-72.2709**	Point
63	65	**42.92907**	**-72.2708**	Point
64	66	**42.92913**	**-72.27077**	Point
65	67	**42.92952**	**-72.27059**	Point
66	68	**42.92928**	**-72.27081**	Point
67	69	**42.92969**	**-72.27067**	Point
68	70	**42.92958**	**-72.27062**	Point
69	72	**42.93021**	**-72.27097**	Point
70	73	**42.93033**	**-72.2711**	Point
71	74	**42.93285**	**-72.27341**	Point
72	76	**42.93343**	**-72.2738**	Point
73	77	**42.93344**	**-72.27379**	Point
74	79	**42.93607**	**-72.2737**	Point
75	80	**42.93656**	**-72.27361**	Point
76	81	**42.93656**	**-72.2736**	Point
77	82	**42.93721**	**-72.27374**	Point
78	83	**42.93721**	**-72.27375**	Point
79	78	**42.93605**	**-72.27371**	Point

80	101	**42.95181**	**-72.26934**	Point
81	100	**42.95168**	**-72.26921**	Point
82	99	**42.95142**	**-72.26913**	Point
83	98	**42.95142**	**-72.26913**	Point
84	75	**42.93287**	**-72.27342**	Point
85	49	**42.92497**	**-72.2712**	Point
86	71	**42.93011**	**-72.27083**	Point
87	84	**42.93721**	**-72.27375**	Point
88	85	**42.9373**	**-72.27379**	Point
89	86	**42.93783**	**-72.27364**	Point
90	87	**42.93781**	**-72.27365**	Point
91	88	**42.93829**	**-72.27301**	Point
92	89	**42.93895**	**-72.27297**	Point
93	90	**42.93858**	**-72.27297**	Point
94	91	**42.93872**	**-72.27297**	Point
95	92	**42.93896**	**-72.27287**	Point
96	93	**42.94014**	**-72.27151**	Point
97	94	**42.94017**	**-72.27151**	Point
98	95	**42.9403**	**-72.27146**	Point
99	96	**42.94029**	**-72.27146**	Point
100	97	**42.94095**	**-72.2715**	Point
101	102	**42.95267**	**-72.26941**	Point
102	103	**42.94292**	**-72.27176**	Point
103	104	**42.94317**	**-72.27177**	Point
104	105	**42.94332**	**-72.27178**	Point
105	106	**42.94407**	**-72.27163**	Point
106	107	**42.94394**	**-72.27184**	Point
107	108	**42.94305**	**-72.27184**	Point
108	109	**42.94298**	**-72.27183**	Point
109	110	**42.94158**	**-72.27179**	Point