2009

Trace Metals in Peabody Pond and Jordon Pond: a Case Study of New England’s Historic Landscape Change in the Former Mill Ponds of the Scituate Reservoir Watershed, Rhode Island

Emily Harrison

University of Vermont

Follow this and additional works at: https://scholarworks.uvm.edu/graddis

Recommended Citation

Harrison, Emily, "Trace Metals in Peabody Pond and Jordon Pond: a Case Study of New England’s Historic Landscape Change in the Former Mill Ponds of the Scituate Reservoir Watershed, Rhode Island" (2009). Graduate College Dissertations and Theses. 103.

https://scholarworks.uvm.edu/graddis/103

This Thesis is brought to you for free and open access by the Dissertations and Theses at ScholarWorks @ UVM. It has been accepted for inclusion in Graduate College Dissertations and Theses by an authorized administrator of ScholarWorks @ UVM. For more information, please contact donna.omalley@uvm.edu.
TRACE METALS IN PEABODY POND AND JORDON POND: A CASE STUDY OF NEW ENGLAND’S HISTORIC LANDSCAPE CHANGE IN THE FORMER MILL PONDS OF THE SCITUATE RESERVOIR WATERSHED, RHODE ISLAND

A Thesis Presented

by

Emily Harrison

to

The Faculty of the Graduate College

of

The University of Vermont

In Partial Fulfillment of the Requirements for the Degree of Master of Arts Specializing in Geography

August, 2008
Accepted by the Faculty of the Graduate College, The University of Vermont, in partial fulfillment of the requirements for the degree of Master of Arts, specializing in Geography.

Thesis Examination Committee:

Lesley-Ann Dupigny-Ghoux, Ph.D.  
Adviser

Cheryl Morse Dunkley, Ph.D.  
Chairperson

Robert McCullough, Ph.D.  
Vice President for Research and Dean of Graduate Studies

Date: August 11, 2008
ABSTRACT

The North American landscape changed tremendously following the arrival of European settlers. Before European arrival, New England’s landscape was primarily forested. As Europeans moved inland from the eastern seaboard, they cleared the forest for settlement and agricultural use. Eventually the Industrial Revolution made a different kind of mark on the landscape. Starting in the late 1790s, the textile mill industry developed throughout the region. Mills were located along swift moving rivers, which later produced power when dams were created along them. Following the early 1900s mill production decreased, leading to the abandonment of many mills and their adjacent dammed mill ponds. However, the environmental changes wrought by the mill ponds still exist in New England’s landscape. Large volumes of fine sediment have since built up in some of these former mill ponds and concerns about the sediment and water quality have become widespread. Today many former textile mill rivers throughout the U.S and Europe have been tested in an attempt to determine current contamination levels and to apply appropriate strategies if necessary to reduce pollutants to acceptable levels. Little is known about water and sediment quality of the former mill ponds in Scituate, Rhode Island. This research sought to address this problem by conducting trace metal testing of two mill ponds in the Scituate River Watershed: Peabody Pond and Jordon Pond. Results revealed that both ponds contain pollutants from present and past sources, but that contemporary land use practices may be the most harmful to water and sediment quality. Existing mill metal piping left on the landscape and present-day motorways and urban runoff contain large quantities of suspended solids such as copper, lead and zinc with lead showing the highest concentration levels of all metals tested. This research demonstrates that our past landscape activities, specifically New England’s historic textile production, still influences present environmental conditions, and that as human activities on the landscape change, so do threats to environmental quality.
ACKNOWLEDGEMENTS

I am deeply appreciative to the University of Vermont, the Graduate College and the Department of Geography for giving me the opportunity to complete this thesis through a Graduate Teaching Fellowship. This thesis would not have been possible without support and guidance from my advisor Lesley-Ann Dupigny-Giroux. Special thanks is given to Richard Blodgett of the Providence Water Board for suggesting this topic and allowing me the opportunity to research these ponds and allowing me access within the watershed for an up close and personal view of the area. I would also like to thank the Scituate Town Hall and Library for allowing me to use their facilities for countless hours to access priceless historical data not found anywhere else. Additional appreciation is given to Rob and Lenny from TG&B, an Environmental Consulting Firm from Falmouth, Mass. Without their help I would not have been able to receive the sediment results that were so critically needed for this paper. Lastly and most importantly, I would like to thank my family and friends for their endless support and encouragement over the past few years.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................... ii

LIST OF TABLES ............................................................................................................................... v

LIST OF FIGURES ............................................................................................................................. vi

LITERATURE REVIEW ...................................................................................................................... 1

- North American Landscape Pre Europeans to Early European Arrival ............. 1
  - Landscape Change ..................................................................................................................... 3
  - Industrialization ....................................................................................................................... 4
  - Rhode Island History ............................................................................................................... 6
    - Scituate, Rhode Island ............................................................................................................. 7
    - Clayville Village: Scituate, Rhode Island ............................................................................. 8
  - Mills and Mill Pond History ................................................................................................... 10
  - Dams ........................................................................................................................................ 11

- Contemporary Landscape Population Change in Southern New England ... 14

- Research on Non-Point Sources of Trace Metals .................................................. 16
  - “Trace Metals in Peabody Pond and Jordon Pond: A Case Study of New England’s Historic Landscape Change in the Former Mill Ponds of the Scituate Reservoir Watershed, Rhode Island”

1. ABSTRACT ................................................................................................................................. 21

2. INTRODUCTION ....................................................................................................................... 22

3. STUDY AREA ............................................................................................................................ 24

4. METHODS ................................................................................................................................. 29

  Textual Analysis ......................................................................................................................... 29
LIST OF TABLES

Table 1. Total core length of each core in Peabody and Jordon Pond……………………..39
Table 2: pH levels of core sections in Peabody Pond………………………………………..39
Table 3: pH levels of core sections in Jordon Pond………………………………………..40
Table 4. Rhode Island Department of Environmental Management Direct Exposure
Criteria: Inorganics……………………………………………………………………………….49
Table 5. Selected Trace Metals and their Maximum Contaminant Level (MCLs)……..49
LIST OF FIGURES

Figure 1. Map of Scituate, Rhode Island and the surrounding areas………………25

Figure 2. Ponaganset and Moswaniscut Rivers flowing through Scituate, Rhode
Island into Reservoir…………………………………………………………...26

Figure 3. Locations of mills and bodies of water in Scituate, 1870………………27

Figure 4. Survey map of Peabody Pond, 1917……………………………………28

Figure 5. Annual summary of forest (a), housing (b), and water (c) square acreage and
square mileage (d) of total road coverage within Peabody Pond………………...34

Figure 6. Annual summary of forest (a), housing (b), and water (c) square acreage and
square mileage (d) of total road coverage within Jordan Pond……………….35

Figure 7. Black and white aerial composites of Jordan and Peabody Ponds from 1939 to
2004………………………………………………………………………………………...36

Figure 8. Black and white composites from 2003 showing the location of the cores taken
in Peabody Pond (a) and Jordan Pond (b)………………………………………………38

Figure 9. Analysis of trace metal counts (in ppm) of four cores extracted from Peabody
Pond………………………………………………………………………………………43

Figure 10. Analysis of trace metal counts (in ppm) of four cores extracted from Jordan
Pond………………………………………………………………………………………44
LITERATURE REVIEW

New England’s landscape has changed considerably over the past 500 years. Not only has its forest cover shifted in both extent and composition over time, but activities now long gone such as textile production, still influence current conditions such as water quality. A review of the literature on historic landscape change in New England, specifically on the built environment, as well as the release of polluting trace metals helps to piece together the picture of past practices and contemporary water quality in the Scituate River Watershed of Rhode Island. The first section of this literature review discusses how New England’s landscape as a region changed over time through human interference and then focuses in on the area of study of Scituate, Rhode Island. Secondly, the literature review considers the different reasons for runoff trace metal pollutants and why higher metal levels can be found in the environment today.

North American Landscape Pre Europeans to Early Arrival

Before embarking upon any type of research it is important to understand the background context of the area of interest. The landscape of the Americas underwent tremendous change when European settlers landed in what is now the United States. Before European arrival, the landscape was modified by Native Americans who selectively burned some forests which then became grasslands for hunting grounds (Denevan, 1992). The pre-colonial landscape of New England was a patchwork of salt
marshes along the shore, dense forests, cleared areas in the forest, several vegetation zones and a wide variety of mammals that were not seen in Europe (Cronon, 1983). Most of the forestland in North America was located in the moist East and Northwest regions, and at the time of European arrival had already been altered by Native American land-use practices (Mann, 2002). Since natural and human disturbance was infrequent and local, the pre-European landscapes including the coastal areas were predominantly forested and open land habitats were uncommon (Foster and Motzkin, 2003).

At the contact period, native peoples lived in small villages throughout the Northeast and especially along river valleys and the seacoast – some seasonally and some year round (Braun and Braun, 1994). Each village was home to a group of related families. They usually built their settlements in places favorable for farming and fishing. Early European visitors remarked that the land was cleared for settlement all along the southern coast, on the offshore islands and inland along the river valleys, ponds and lakes (Braun and Braun, 1994). Unlike the Native Americans who used fire to clear the land of underbrush in the forest, Europeans used fire for deforestation (Cronon, 1983). Although European settlement began along the coast where the land was cleared, over time the Europeans started moving inland, changing the landscape even further. Eventually the predominant forest in the area disappeared due to clearing for land and vegetation use developed by the Europeans (Foster and Motzkin, 2003). However, true historical data are fragmentary and often times uncertain (Foster et. al., 2002) which makes an accurate representation of the land (pre and early European settlement) hard to obtain. Land use practices in the United States for pre-European settlements have been sparsely reported in
the literature. Much of the research on land-use history in New England comes from David R. Foster (1999, 2002, 2003) at Harvard University. His work provides better insight into vegetation and landscape change dating back to the 1700s.

**Landscape Changes**

Land-use transformations involving deforestation, intensive agriculture, farm abandonment, reforestation and human population increase have led to sweeping changes in wildlife assemblages, abundances and distributions in the eastern United States over the past four centuries (Foster et. al., 2002). Deforestation of the landscape was one of the most sweeping transformations resulting from European settlement in New England (Cronon, 1983).

One cause of American deforestation was the construction of mills for supplying settlers’ needs. The earliest mills built in New England were sawmills, gristmills and fulling mills, which were used for finishing hand-woven woolen cloth. Almost every village of any size had at least one of these mills if streams were suitable for waterpower (Hamilton, 1964). New England’s rivers were generally fast moving mills were built along these bodies of water because they had enough force behind them to turn a wheel (Norton, 1987). Once major building obstacles (boulders, roots from trees) were removed, mill construction began, as did the clearing of land for storage sheds and small houses for mill workers (Macaulay, 1983).
In 1790 the Slater Mill, the first successful water powered cotton-spinning factory in the United States, began the new age of the Industrial Revolution (Slater Mill, 2006). Samuel Slater built machines from the recollections of those he had seen in England and Americanized the process of producing cotton (White, 1967). As this success inspired others to build mills and take advantage of the waterpower, new villages were built on former fields and forests.

Long before the waters of these rivers were used to power textile mills via a network of dams and canals, farmers relied on the rivers to provide food for their families. Farming was the first profitable way to live in the Americas. In the spring, when winter supplies ran low, colonists would go fishing with ease because salmon was very plentiful during colonial times (Steinberg, 2002). As textile mills became very successful throughout New England, farming became unprofitable. Farm abandonment started in the mid 1800s; thereafter forests gradually grew back on forgotten fields.

**Industrialization**

The decline in agriculture was primarily related to the growth of the Industrial Revolution and the textile industry. During the late 1700s mills began to surface on the American landscape in order to make supplies that were no longer being sent over from England, but which were in great demand by the people in New England. Mill owners had to find the right place along the river to provide enough power to turn the wheel for the mill. The placement of the mills depended on a few key factors. Among the most important criteria were: access to the river for power, availability of a road or canal for
transportation and the ability to determine the highest available head of the river, good for waterwheel movement (Macaulay, 1983). River modification almost always accompanied the building of these mills through the construction of dams, canals and spillways (Steinberg, 2002; Macaulay, 1983). The canals were built primarily to help run/turn the wheel of the mill.

With the textile industry dominating the landscape, the Blackstone River Valley of Massachusetts and Rhode Island became the “Birthplace of the American Industrial Revolution.” This is where America made the transformation from farm to factory. With the success of the Slater Mill, beginning the new age of the Industrial Revolution (Blackstone River Valley, 2004) this inspired others to build mills and take advantage of the water power. As a result new villages sprung up on the landscape.

Throughout the next few decades of the 19th century the mill industry became very popular, with the influence of skilled English and Irish immigrants coming to New England bringing the necessary expertise for running the industry. These mills were all located along swift moving rivers, which later produced power when dams were created along them. The creation of these dams flooded vast areas of farmland that had already been abandoned, thereby changing the landscape even further.

Water was fundamentally important for virtually all early industrial processes, be it for power, transport, washing, sieving (separating desired elements from unwanted materials) or cooling (Rees, 1997). Mill ponds were typically constructed either by digging a small depression and building retaining walls around it, or by building walls in an existing depression to hold the water needed to run the mills (Wood and Barker,
Depending upon the primary function of the mill, water was used to clean raw materials (scouring) such as wool, in finished products to drive machinery, to supply steam in the spinning and weaving processes and/or to dye yarn for finished textiles (Wood and Barker, 2000).

**Rhode Island History**

This study focused on the region of Scituate, Rhode Island where many of the early mills in New England were constructed. The beginning of Rhode Island’s history involved five different settlements: Pocasset, Shawomet, Pawtuxet, Newport and Providence (McLoughlin, 1978). It was the settlement by English Clergyman Roger Williams in Providence at the head of Narragansett Bay in 1636 that was of greatest importance to this study. The Cononicus and Miatonomi Sachems of the Narragansett Native Americans granted Williams a deed of land from the Narragansett Bay to the Pawtuxet River. He called the new village that was created on this land Providence (Conley, 1986; McLoughlin, 1978; R.I. Historical Preservation Commission, 1980). Although this friendship with the Indians was the key to opening this region of the New World, the early settlements in Rhode Island grew very slowly. There were only 100 people in Providence by 1638 and about 350-400 people by 1675 (McLoughlin, 1978). By 1730, the total population of the state of Rhode Island was 17,935, an increase of a little more than 10,000 people in less than a 30-year period (Conley, 1986).
During the era of 1790-1845, rapid immigration occurred (Norton, 1987). From roughly mid-1820 onward, Irish Catholics came to Rhode Island to work on such projects as Fort Adams Mill in Newport, the Blackstone Canal and railroads, as well as the textile mills and metal factories that began to dot and darken the local landscape (Conley, 1986; Macaulay, 1983; Norton, 1987). It was during this time that the American Industrial Revolution transformed the state’s economy from commercial to industrial.

Scituate, Rhode Island

In 1703, Scituate’s first settler was John Mathewson, signer of the Declaration of Independence. Emigrants from Scituate, Massachusetts first settled in Rhode Island in 1710. The original spelling of the town’s name was “Satuit”, an Indian word meaning “cold brook” (Smith, 1976). Scituate was originally part of the Providence Plantation, but in 1730, Scituate lands became independent from Providence and the town was officially incorporated into Rhode Island in 1731. At that time Scituate’s boundaries also encompassed the present day town of Foster, with Gloucester to the North, Providence to the east, Warwick to the south and the state of Connecticut to the West.

During the 1700’s, Scituate was dominated by an agricultural economy with a heavy dependence on the land (R.I. Historical Preservation Commission, 1980). Two powerful rivers, the Moswansicut and Ponaganset, flowed through Scituate and were of great importance to individual farm economies (Steinberg, 2002), as well as the soon-to-be established mill industry. Mill location was more a function of the presence of a river for power supply and less so on village size (Hamilton, 1964). By the end of the 1700s
and into the early 1800s the textile industry had developed, with textile mills quickly
dotting the landscape.

**Clayville**

Beginning at the end of the 1700’s, Scituate’s population began to grow, climbing
to over 2,300 people (R.I. Census, 2000). This led to the creation of small villages
throughout the town. There were a total of sixteen villages, with present day Clayville
being one of the more industrialized areas in the town. In 1781, the land that would be
called Clayville, (which was originally part of Scituate) was divided when the western
half of Scituate became incorporated as the town of Foster. Before this, the area was
called “the outlands” or the Providence Woods (Warren, 1988; Sabetta, 1989).

While Clayville would eventually become home to one of the bigger
industrialized areas in Rhode Island, the population grew slowly at first. Even though
there were early settlers throughout Scituate in the 1700s, this particular area did not
become officially settled until 1826 by General Josiah Whitaker. Whitaker operated a
mill that produced tortoise-shell combs. This created the first name of the area, Comb
Factory Village (Warren, 1988; Sarkesian, 1987). The name Clayville was not used until
1829 when the village was dedicated to Kentucky statesman Henry Clay, a presidential
candidate in 1824 who was very popular in New England towns and regarded as a
national hero (Sarkesian, 1987; Sabetta, 1989). In 1898, Clayville became a stop along
the Providence & Danielson Street Railways Company line that traveled from Providence
R.I into Connecticut (Warren, 1988; Janis, 1985). The village was so industrialized that
for two decades in the early 1900s there was a trolley service that connected Clayville to larger population centers, allowing commuters to travel back and forth (Janis, 1985; Warren, 1988).

Even though this area in Scituate had a “booming” economy, the water quality was becoming degraded by sewage and mill pollutants. Immediate remedial action was necessary. April 21, 1915 became known as Black Friday in the town of Scituate, Rhode Island, a day that changed the history of that area forever. On that day, the Rhode Island General Assembly voted to use 14,800 acres of land in Scituate (38% of the town) (Scituate Reservoir Watershed Management Plan, 1990) to create a reservoir to supply fresh water to Greater Providence. This project resulted in the condemnation of 1,195 buildings, including 375 houses, 7 schools, 6 churches, 6 mills, 30 dairy farms, 11 ice houses, post offices and an electric railway system (Town of Scituate, 2004; Janis, 1985).

With the construction of the Scituate Reservoir and the subsequent closing and demolition of Clayville mills, the village’s economy died and significant emigration occurred. Between the years 1920 and 1930 a population decline of close to 1000 people occurred (R.I. Census, 2000). In 1980 the R.I Historical Preservation Commission recommended that the Clayville Historic District be placed on the National Registrar of Historic Places, (Sarkesian, 1987) and by 1988 Clayville was added. Today Clayville contains physical evidence of demolished mills and abandoned water systems, which are important in understanding the former industrial economy of the village. The tranquility of modern Clayville means it would be missed on the landscape by many passers-by (Sabetta, 1989).
Mills and Mill Pond History

Although Scituate Reservoir is one of the most closely monitored bodies of clean water in the state, the water and sediment quality of many tributaries of major rivers along which mills had operated, has to date been neglected. The Providence Water Board has begun to examine these old abandoned millponds located in the area to determine whether any contamination persists in these locations. Peabody Pond, which is located downstream of the Clayville Mills, is believed to have possible sediment contamination built up behind the dam from the mill era, and in order to understand analytical findings, one must take into account the types of the former mills in Clayville, prior to the region’s condemnation for constructing the Scituate Reservoir.

The small water-powered cotton mill located at present day Jordon Pond gave way to the comb-making factory of Joseph Whitaker and Moses Richardson in 1826. This mill was then converted to rubber footwear production in 1847 and changed again to cotton production in 1853 (R.I. Historic Preservation Commission, 1980). The mill burned down that very year and was rebuilt in 1857 as a cotton mill. A second mill, the Lower Clayville Mill, located downstream, was also built in 1857.

By 1863 the mills were bought by Lindsay Jordon, a manufacturer of printed cloth. During the 1870s the Clayville Mills were sold to a Mr. Stephen Weeden who manufactured cotton yarn, but by this time production had fallen sharply due to insufficient water. The mills were then sold to the Joslin Manufacturing Company in 1906, which produced corset string and laces. However, by 1924 the mills of Clayville
were demolished. All that is left today of these mills are their foundations. These historical transformations set the stage for quantifying present-day sediment contents.

Mill production grew steadily in the 1800s with the production of many different textiles. However, following the early 1900s mill production decreased, leading to the abandonment of many mills and their adjacent millponds. At present, many of these dams along the mill ponds are eroding, which if not tended to quickly, will cause increasing instability. In this scenario, a rainstorm with high enough intensity or volume could potentially cause a given dam to fail, releasing its contents downstream.

Over time, large volumes of fine sediment have built up in some of these former mill ponds, reducing water depths (Wood and Barker, 2000). Today, many former textile mill rivers and mill ponds throughout the U.S. and Europe have been tested in an attempt to determine current contamination levels, so that if necessary, appropriate strategies can be implemented to reduce pollutants back to acceptable levels. The Providence Water Board is beginning to analyze ponds within its purview to determine whether specific ones display contaminated water and/or sediment.

Dams

Given that the primary use of the millponds has long since ended, a new concern arises about the current water quality and long-term dependability of these ponds. This new concern has sparked a debate about whether to remove these dams or try to repair
them. Many dams around existing millponds are past their designed lifespan and need to either be taken down or repaired to acceptable safety standards.

Dam removal has been an issue throughout the United States for the past few decades. Over 76,000 dams have been constructed on American rivers to provide services such as flood protection, water storage, hydroelectric power and navigation (Pohl, 2002; Graf, 1999; Born and Genskow, 1998). With an expected lifespan of only about 50 years (Wade, 1999), many of these structures are deteriorating and expensive repairs are often needed to ensure that the dams remain safe (Pollard and Reed, 2004). Governments and dam owners face tough decisions regarding the repair or removal of these structures on a regular basis (Born and Genskow, 1998).

Among the water quality problems associated with dams are the accumulation of contaminants and shallowing due to rapid sedimentation (Born and Genskow, 1998). Dam removal can potentially affect physical, chemical and biological components of the ecosystem by releasing large volumes of sediment that have accumulated upstream of many old dams. Following dam removal, downstream export of this sediment can affect biogeochemical cycles as well as habitat use by various species (Bushaw et. al, 2002). An example of this is the removal of the Fort Edwards Dam in New York, which released several tons of contaminated sediment. At present, contaminated sediment has settled over a 300km length of the Hudson River and the commercial fishing of striped bass and other species is still banned due to the risk of bioaccumulation. Clean up effects continue today (Pohl, 2002; Economist, 2000). As of 2008 the clean-up is still moving forward.
Wastes from pulp and paper mills that used bleach to whiten paper before being dumped into the rivers and ponds were problematic not just in Rhode Island, but throughout New England and the U.K. as well (Wigilius, 1988, Huber, 1988). During the early to mid 20th century, rivers in New England were among the most polluted rivers in the United States. Outbreaks of typhoid fever and other infectious diseases were common in urban areas that used polluted rivers as a source of drinking water (Robinson, 2003). As late as the 1960s more than 120 million gallons per day of wastewater were dumped into the Merrimack River (in New Hampshire), and in the 1970s the Connecticut River was so polluted it was referred to as a “landscape sewer” (Robinson, 2003).

Phosphorous levels were very high in these waters and sediment due to the use of certain detergents containing chloride and nitrate. Arsenic levels at high concentrations can be hazardous to human health. High arsenic levels caused by mill dumping and also privately owned wells lined with bedrock have also been found throughout the United States (Ayotte, 2003). Recently there has been an attempt to clean up contamination in the ponds and the soil left from mills decades or even centuries ago. In June 2003, in Twisp, Washington, the EPA removed 1,000 cubic yards of contaminated materials from Alder millpond (Rees, 2003). This ore concentrating mill for copper and gold left high contamination levels of arsenic, lead and other metals. EPA members for the Merrimack River in New England have also made attempts at lowering the level of contamination by banning the use of detergents used in these mills (Robinson, 2003).

There are many complex issues involved in determining whether dams should remain on the landscape or be taken down. Dams interrupt connectivity between
upstream and downstream segments of streams creating barriers to fish migration, 
inundating stream habitat and altering flow, temperature and sediment regimes (Pollard 
and Reed, 2004; Smith et. al, 2000). The state of New Hampshire is institutionalizing the 
option of dam removal for dams that are no longer serving their purpose and rapidly 
deteriorating. For example, Lindloff (2003) studied the removal of the McGoldrick dam 
that was built in 1828, around the same time as the Peabody Pond dam. The dam was 
used to provide water for a canal and power generation for eight manufacturing facilities. 

By 1950 McGoldrick dam was no longer needed to serve this particular service. 
Testing of the low sediment accumulations showed that it was free of contamination. It 
should be noted that the results for the McGoldrick dam should not be extrapolated to the 
case of Peabody Pond due to the potential differences in the type and duration of mill 
activity. McGoldrick might not have had any other type of mill upstream. Even though 
many mill ponds in New England can be classified as contaminated due to mill and local 
runoff, it is important to mention that not all water bodies on sediment associated with 
mill activity are contaminated, as shown in the McGoldrick example.

**Contemporary Landscape Population Change in Southern New England**

The region classified as New England consists of 6 states: Maine, New 
Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut. As of 2000, the 
census population of New England stood at 13,922,517. Southern New England contains 
the states of Connecticut, Rhode Island and Massachusetts. As of the year 2000 the 
population of the area comprised of 10,802,981 people, averaging just over 77.5% of the
total population of the area (U.S. Census Bureau & Statewide Planning, 2000). Over the past century (1900-2000) the population of Southern New England has grown to 6,660,659, an increase of 181.9%.

In 1790, Rhode Island’s population was listed at 68,825 people with Scituate having 2,315 people (U.S. Bureau of the Census, 2000). Throughout the next two centuries, Scituate’s population rose steadily, reaching over 4500 people in 1850 before declining during and after the Civil War to 3100 people by 1890. Over the next few decades, however, during Scituate’s industrial boom, the population rose to almost 3500 people. By the 1930s, after the condemnation of all the mills, Scituate’s population dropped to 2300 and has been rising slowly ever since. By the 1960s, Scituate’s population reached 5200, and had jumped to over 8400 by the 1980s. In 2000, the U.S. Bureau of the Census listed the population of Scituate as 10,324 people. This jump in one town’s population can have effects on the contemporary environment due to urban/suburban dumping and runoff of pollutants into nearby water bodies.

Over the past 50 years (1950-2000) the landscape of Rhode Island has been home to the creation of new factories for goods and large buildings both for commercial and residential use. Scituate on the other hand has taken a slightly different approach to the change in its landscape. Residential growth has been noted, but few large or new industrial or commercial buildings have been built. Growth has flourished in high population centers. Though less industrial and commercial growth has occurred in the center of Scituate, residential areas have grown. Population growth is a potential contributor to the trace metals observed in pond sediment today.
Research on Non-Point Sources of Trace Metals

While dams create an issue of possible contamination due to sedimentation, runoff is also a major contributor to water quality. Different types of runoff in an area can create large problems depending on the source and content. Traffic, road construction and road maintenance all combine to act as contributors to environmental pollutions (Legret and Pagatto, 1999). Non-point sources that include runoff from agricultural, urban and highway surfaces, and lawns and natural areas, account for 80 percent of the contamination of waters in the United States. These eventually settle into the soil or sediment (Infrastructure, 1999). Temporary pulses of pollution usually accompany road work, while seasonal contaminants can be the result of road salt, and runoff contaminants associated with vehicular exhaust, pavement and tire wear (Legret and Pagatto, 1999). Storm water runoff mobilizes large quantities of contaminants from the urban environment (Charlatchka and Cambier, 1997).

Motorway pavement runoff water contains a large quantity of suspended solids, some of which are heavy metals. A previous study by Legret and Pagotto (1999) discusses pollutant loadings in the runoff waters from a major rural highway. Although road traffic and maintenance are not of the same magnitude in the Scituate study area as in Legret and Pagotto’s study area, copper, lead and zinc were found in both.

This thesis focused on the ways in which copper, lead and zinc entered the environment as a consequence of both historical mill activities and present day uses. In
order to understand the significance of these trace metals better, a short analysis of how they are found in the environment is discussed below.

Copper (Cu) is a reddish metal that occurs naturally in rock, soil, sediment, water and air. The average concentration in the earth’s crust is about 50 parts copper per million parts soil (Environmental Bureau of Investigation - Copper, 2007). Copper can be released into the environment by both natural sources and human activities. It can become airborne through the burning of fossil fuels, along with windblown dust, decaying vegetation, forest fires and sea spray (Lenntech, 2007). Once airborne, copper can remain in suspension until it precipitates out onto soil and into water.

Zinc (Zn) is one of the most common elements in the earth’s crust and one of the most commonly used metals in the world. Zinc can enter the air both from natural and human occurrences. Most zinc enters the environment as the result of human activities such as mining, purifying of zinc, lead and cadmium ores, steel production, coal burning and burning of wastes (Environmental Bureau of Investigation - Zinc, 2007). Airborne zinc is present mostly as fine dust particles that settle slowly by dry deposition (Eco-USA, 1994) but much more quickly by wet processes (rain, snow).

Lead (Pb) is the most common contaminant in the soil, averaging between 15-50 parts lead per million parts soil. Contamination occurs at levels above 500 ppm. Lead contamination results from scrap metal (lead pipes or old roofing pieces), auto exhaust from leaded gas, fallout on roadsides and even old orchards due to lead arsenates that were heavily used until World War II (Maine Soil Testing Service, 1998). Lead levels are usually higher in cities, near roadways and industries that use lead as well as in the soil.
near homes where lead paint flakes have fallen off (Yeager, 2007). The study area is located near a moderately traveled roadway and is downstream from an abandoned mill site with lots of metal piping left throughout the landscape.

These three trace metals are of importance to the current study, making it imperative to outline their pathways through the environment including sediment. Over 50% of the total pollutant inputs for suspended solids, Polycyclic aromatic hydrocarbon (PAH’s), Pb and Zn, in water bodies come from the highway (Hoffman, Latimer et. al, 1985). Wear and tear of vehicles, dropping of oil, grease, rust, hydrocarbons, rubber particles and other solid materials on the highway surface are often washed off the highways during rain and snow events (Infrastructure, 1999). Leaded gasoline was banned in 1986, but lead is still being deposited on highway surfaces through paints used on right of ways and atmospheric deposition in the environment (Charlatchka and Cambier, 1997). Copper comes from brake linings, (Legret and Pagatto, 1999) and street dust also often contain elevated concentrations of a range of toxic metals (Pb, Cd, Cu and Zn) (Harrison et. al, 1981), which can wash into bodies of water and eventually settle to the bottom.

A previous study by Koivo and Oravainen (1983) is concerned with the impacts of industrial and municipal waste discharge within lakes. This study looks at how human impact on the land affects the lakes. Although these were water samples and not sediment, findings showed that zinc levels were consistently low throughout the study.

This literature review is intended to help set the stage for my thesis, which deals with the analysis of sediment trace metals in an abandoned historic mill pond, as well as
understanding the nature of past and ongoing environmental damage to the area.
Trace Metals in Peabody Pond and Jordon Pond: A Case Study of New England’s Historic Landscape Change in the Former Mill Ponds of the Scituate Reservoir Watershed, Rhode Island

Emily R. Harrison
The University of Vermont, Burlington, VT

In preparation for submission to Applied Geography
ABSTRACT

Peabody and Jordon Ponds, abandoned industrial mill ponds within the Scituate Reservoir Watershed in Rhode Island were analyzed using sediment core analysis to determine whether the sediments within the ponds were contaminated with trace metals as a result of historic mill activities. Although high levels of lead were discovered in Jordon Pond, the source appears to be from contemporary road and development activities, rather than historic mill activities or other previous land use activities. This paper contributes to the limited literature on historic mill pond analysis, and to research on contemporary development-related environmental changes in New England.
INTRODUCTION

The landscape of New England is always changing. Soil and sediment analysis can tell us a little about the pollution, if any, of a particular area over time. With the arrival of Europeans, North America was transformed from being primarily forested (1600s) to agriculture fields for crops and pasture (1700s), and to a landscape of textiles production (1800s). Over time, the textile industry diminished and people moved away abandoning the land. In the 20th century, people moved back and resettled the land, turning it into a residential landscape. Landscape change over time has influenced the quality of the contemporary environment. Both past and present lifestyles affect the current landscape.

Historic mill pond analysis is a topic with few existing studies from which to extract an understanding of the nature of past and ongoing environmental damage. Much of the available literature is more focused on the residual effects of pulp and paper mills on aquatic life in these bodies of water (Wood, et. al., 2001; Sepulveda, et. al, 2004; Greenfield and Bart Jr., 2005), and less so on the textile mills of a century ago. Across New England, the landscape is dotted with numerous mill ponds that have been abandoned and no longer serve their original purpose (Wood and Barker, 2000). This abandonment stems from changes in the landscape that have occurred over the past several hundred years.

Mill ponds were typically constructed either by digging a small depression and building retaining walls around it, or by building walls in an existing depression to hold
the water needed to run the mills (Wood and Barker, 2000). Depending on the function of the mill water, either for cleaning raw materials, supplying steam for spinning processes or for dyeing yarn or finished textiles, the water within the pond was normally clean (Rees, 1997; Giles and Goodall, 1992). However, after running through the mills, the water could be largely contaminated when released back into the environment (Giles and Goodall, 1992; Wood and Barker, 2000).

In virtually all early industrial processes, water was critically important (Rees, 1997). The issue today is that no in-depth investigations have been performed on possible sediment contamination in the existing millponds. Since the primary use of the mill ponds is now obsolete, a new concern arises about the quality and dependability of these ponds. Dams currently hold back sediment in these ponds, and with an expected lifespan of only roughly 50 years (Wade, 1999), many of these structures are deteriorating and expensive repairs are often needed to ensure dam integrity (Pollard and Reed, 2004). Among the water quality problems associated with dams are the accumulation of contaminants and shallowing due to rapid sedimentation (Born and Genskow, 1998). Downstream export of this sediment following dam removal can affect biogeochemical cycles as well as habitat use by various species (Bushaw et. al, 2002).

In the town of Scituate, Rhode Island, potential dam removal along existing mill ponds has sparked a debate over a series of sediment and water quality issues should the water and sediment be released downstream into the Scituate Reservoir. This is of particular interest because half the state of Rhode Island depends on the reservoir for clean water. The Providence Water Board, which oversees the construction and
preservation of the Scituate Reservoir, has expressed strong sentiments about dam
preservation in the Scituate watershed. Watersheds serve as migratory stops, pathways
and permanent residences for wildlife (Economist, 2000). The Providence Water Board is
also very concerned about the potential effects that dam removal and the subsequent
releasing of the sediment could have on the reservoir over time.

Thus, the primary goal of this research is to analyze sediment cores in two mill
ponds in Scituate, Rhode Island (Jordon Pond and Peabody Pond) to better understand the
relationship between the present day content and the wastes that were dumped there over
a century ago. The three research questions posed were:

- What are the present-day sediment contents within Peabody and Jordon Ponds?
- Does historic mill activity pose more of an environmental threat today than we
  might think?
- What implications does Peabody and Jordon Pond’s sediment content have for the
  future of the dams, mill ponds and the quality of the Scituate Reservoir?

Study Area

This paper focuses on the town of Scituate, Rhode Island, which is located in
Providence County and the Scituate Reservoir which it encompasses. The adjacent town
of Foster, also located in Providence County has been included for completeness as
shown in Figure 1.
The town of Scituate covers an area of 52 square miles centered at 41.79°N, 71.65°W and is located approximately ten miles west of Providence, the capital of Rhode Island. Two main rivers, the Ponagansett, and Moswancut, flow southeast and southwest respectively through the town until they reach the Scituate Reservoir (Figure 2).
Figure 2: Ponaganset and Moswaniscut Rivers flowing through Scituate, Rhode Island into the Scituate Reservoir

Textile mills began growing on the landscape within Scituate during the early 1800s. Given that the contamination of present day millponds is contingent on past use, the historical context of the study area needs to be highlighted.

There are 10 millponds in the Scituate watershed owned by the Providence Water Board. Peabody Pond (Figure 3), located in the southwest corner of Scituate, was one of two ponds selected for this study for a number of reasons. It is one of the only mill ponds left with residual mill foundations on the land within the Scituate Watershed. The Peabody dam has not been tampered with or breached in any way. In addition, the pond was easily accessible with water shallow enough for extracting sediment cores, that
otherwise would have involved the use of a crane for drilling. As the Scituate Beers Maps show (Figure 4), during the 1870s Peabody Pond was actually made up of three ponds not the two shown on the 20\textsuperscript{th} century map.

![1870 Scituate Beers Map](image)

**Figure 3: Locations of mills and bodies of water in Scituate, 1870**
Figure 4: Survey map of Scituate Reservoir in 1917, highlights the Peabody Pond (which was called Rockland Pond at the time)

Data courtesy of Water Supply Board Scituate Reservoir

Two dams in Peabody Pond were breached during construction of the Scituate Reservoir in the 1920s. Today these two pond areas are reverting to a marshy environment, leaving one dam to contain the remnants of the Clayville Mills. This lone remaining dam is leaky and has been so documented since 1917 by surveyors during a land survey by the Water Supply Board prior to creating the Scituate Reservoir.

The selected study areas cover 1.5 sq. miles around Peabody Pond and approximately 1 sq. mile around Jordan Pond. Jordan Pond is located upstream of Peabody Pond in the heart of Clayville, a populated residential area. Jordan Pond was used to power the Clayville Mills during the mill era. Following the condemnation of the
mills, this pond was left on the landscape with no real purpose or use. With the possibility of present day runoff into the pond, any potential contamination found in Jordon Pond would eventually make its way downstream to Peabody Pond, making the coring for Jordon Pond critical for our long-term understanding.

Data gathered from Rhode Island Geographic Information System Data (RIGIS) show the land cover in 1995 to be primarily forest (of different types) with limited residential growth near the outskirts of the study area. The elevation of Rhode Island is relatively low, with the maximum elevation in the study area only reaching just over 400 feet. The Peabody Pond is located in a valley with partially steep slopes on either side which can provide rapid runoff into the pond.

**Methodology**

Both qualitative and quantitative research methods were employed. Sediment coring and analysis was funded by and performed in collaboration with the Providence Water Board.

**Textual Analysis**

Textual analysis of historical Foster and Scituate books, deeds and videotapes were used to identify and quantify settlement patterns and historical mill use in Scituate. Of interest were mill sites, their production types and length of operation, as well as possible runoff from the mills and the residential growth of the area. This type of data analysis yielded information about the operating timeline and products from each mill, and provided insight into soil core contents (e.g. trace metals from bleaching and printing
buildings). Videotapes were used to analyze the area in a different fashion, and over 1000 photographs were used to analyze the area of the pre-flooded reservoir. One video documented a conversation between two women about their lives there in the early 1900s, while another was of Scituate Historian Frank Spenser, showing the lost villages of Scituate between the years of 1906-1926, before the reservoir was built. This visual media provided crucial details about the landscape not available from looking at maps.

While there is a paucity of studies on mill ponds in the existing literature, there is a larger body of work on dams, their removal and ecological consequences (Born and Genskow, 1998; Graf, 1999; Pohl, 2002; Wade, 1999). This body of work provides insight into a dam’s lifespan, the problem with shallowing, the possible occurrence of contaminated sediments and issues of dam removal.

**Mapping Analysis**

The working hypothesis of this study is that, given the mill activity upstream of Peabody Pond, any contamination released by the mills should be found in this undisturbed millpond. Hard-copy aerial photos from the 1930s to the early 1990s taken approximately every ten years were acquired from the Rhode Island Geographic Information System (RIGIS) website to determine how the mill ponds and the area around them have changed over time. The un-rectified photos of Peabody Pond and Jordon Pond were georeferenced to the most recent photo (2004) prior to digitizing and computing total areas of farmland, forests, ponds and residential areas using ESRI’s ArcMap. The coordinates of the 1.5 sq. mile area around Peabody Pond from the 2004
map were applied to the other maps used for digitizing each feature aforementioned. The use of these coordinates ensured spatial consistency across all photos. Similar georectification was applied to Jordon Pond.

Historical maps were used to extract landscape features from over 100 years ago. Hopkins, Beers and Wallings Maps from the 1800s were also used to show human-made changes on the landscape with property ownership and the approximate locations of houses and mills. During field visits to the study area, these maps were helpful in recreating the landscape from the 1800s to the early 1900s. A 1917 Water Supply Board Map of properties condemned for the construction of the Scituate Reservoir also shows the three ponds on the landscape, and how the land was morphing its current land use. USGS topographic maps of Clayville (scale 1:24,000) were also used to extract key landscape characteristics as well as transportation infrastructure around the study area.

Population density maps and federal census data were used to further explore residential land use change as a contributor to millpond usage. Analyzing the growth rate in the town could determine whether housing had contributed to the millponds via dumping or runoff.

*Field Work Sediment Estimates*

In order to compute the required length of core sampling and to identify/locate the best depth of sediment, estimates were taken in both Peabody and Jordon Ponds. From a canoe, four-foot metal rods (that can be twisted together for added length) were driven into the sediment to determine the depth from the surface layer to the bottom or
peat layer. Roughly 15 to 20 sediment estimates were taken and these ranged in depth from 20 inches to 4 feet. In comparison, the 10 sediment estimates taken in Jordon Pond ranged in depths from 12 inches to a little over 3 feet. The total area of Peabody Pond is approximately two-tenths of a square mile. The actual area that could be used for coring in the early spring 2006 season was under one-tenth of a square mile reflecting by dam leaks and drought conditions.

Core Samples

Sediment coring of both Peabody and Jordon mill ponds was performed by two members of TG&B Environmental Consulting Firm from Falmouth, Massachusetts hired by the Providence Water Board. This firm was selected out of three companies in an open competitive bidding process due to their previous sampling services on environmental assessment projects, including many EPA super fund sites (Reynolds and Avakian, 2008). Four cores were taken from each pond. The coring sites were reached in an Achilles inflatable ten foot rubber boat, where cores were extracted using a push/hammer corer with a piston and a 2 and 5/8 inch diameter polycarbonate liner. Once in the tube, the internal suction was then removed to release any extra water present. The core was then placed on a wooden cradle mounted on two sawhorses for proper manipulation.

The cores were then sliced open using an electric shear, and measured with a tape measure in order to divide them into four equal parts. Once divided, a sample taken by scraping the outside of each of the four sections in the core with plastic spoons and the contents were placed into individually tagged jars. Before new sample were taken from
the core, the spoons were washed thoroughly with alkanox solution provided by the
laboratory for this particular kind of testing to remove any type of residual contaminant.
The jars were then sent for laboratory analysis at Premier Laboratory in Dayville, CT in
order to determine changes in sediment characteristics over time.

RESULTS

Digitized Findings

In order to understand the change of land use over the 20\textsuperscript{th} century, digital aerial
photographs were analyzed for both the Peabody Pond and Jordon Pond areas. Four
different land use/land cover types were selected and digitized for quantifying growth or
decline over time in the area of study. The four selected feature types were forest,
water/pond, housing and roads. As shown in Figure 5 for Peabody Pond and Figure 6 for
Jordon Pond, results indicate the expected regression from cleared land to forest over
time.
Figure 5: Annual summary of forest (a), housing (b), and water (c) square acreage and square mileage (d) of total road coverage within Peabody Pond

(* denotes drought)
(^ denotes roads were dirt)
Data courtesy of http://www.wrb.state.ru.us/lawsreds/droughtplan.pdf
Figure 6: Annual summary of forest (a), housing (b), and water (c) square acreage and square mileage (d) of total road coverage within Jordon Pond

The forest area grew at a reasonable rate over time, which was to be expected since the land began in a clear-cut state. However, over the past decade (1995-2005) the total acreage of forest around Peabody Pond declined due to the recent logging efforts to save healthy trees from an outbreak of Sphaeropsis Shoot Blight by allowing more sunlight into the area.

Over the 1939-2004 timeline, road lengths remained relatively constant around
the Peabody Pond but increased around Jordon Pond due to a lack of and increase in new housing developments respectively in the area. Aerial analysis shows dirt surfaces on major roadways around both ponds in the late 1930s. By the 1950s roadways in both areas appeared to be paved with the exception of small dirt driveways in Jordon Pond’s residential area. Peabody Pond’s housing development showed a slight increase over time due to the limited amount of new housing that can be built near the reservoir every year.

The most notable results were observed in the size of the pond over time. 1972 to 2004 has shown a continual decrease in pond size for Peabody Pond, while the 2004 photo of Jordon Pond showed the greatest decrease in size. A contracted timeline of photos is shown in Figure 7.

![Figure 7: Black and white aerial composites of Jordon and Peabody Ponds from 1939 to 2004.](image)
Sediment Core Findings

Four cores were taken from both ponds as shown on Figure 8. Many were taken near roadways, bridges, dams and residential areas with the potential for runoff into the ponds and observations of trace metal findings that may differ greatly from those taken near forested areas. The working hypothesis is that since mill activity ceased over 84 years ago, any contamination produced from these mills would be found in the oldest section of the core (D).

Every section of core was divided into four equal parts depending on length (Table 1) and was analyzed via three tests to determine the likelihood of contaminating existing drinking water supplies should the dam fail. Section A represents the newest part of each core and section D the oldest.
Figure 8: Black and white composites from 2003 showing the location of the cores taken in Peabody Pond (a) and Jordon Pond (b).
Table 1: Total core length of each core in Peabody and Jordon Pond

<table>
<thead>
<tr>
<th>POND</th>
<th>CORE</th>
<th>TOTAL LENGTH (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peabody</td>
<td>1</td>
<td>42</td>
</tr>
<tr>
<td>Peabody</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Peabody</td>
<td>3</td>
<td>40</td>
</tr>
<tr>
<td>Peabody</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>Jordon</td>
<td>1</td>
<td>44</td>
</tr>
<tr>
<td>Jordon</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>Jordon</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Jordon</td>
<td>4</td>
<td>24</td>
</tr>
</tbody>
</table>

The analysis test 9045 in solid waste in Peabody Pond revealed that the pH of the sediment ranged from 5.1 to 5.9 in the four cores. Core 1 was the most acidic sediment with pH 5.1 (Table 2) compared to the rest of the cores. In Jordon Pond, the pH of the sediment ranged from 4.4 to 5.8 with core 2 having the highest acidity out of all the cores (Table 3).

Table 2: pH levels of core sections in Peabody Pond

<table>
<thead>
<tr>
<th>Core</th>
<th>Section A</th>
<th>Section B</th>
<th>Section C</th>
<th>Section D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.1</td>
<td>5.5</td>
<td>5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>2</td>
<td>5.7</td>
<td>5.6</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>3</td>
<td>5.8</td>
<td>5.7</td>
<td>5.9</td>
<td>5.9</td>
</tr>
<tr>
<td>4</td>
<td>5.6</td>
<td>5.2</td>
<td>5.8</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Table 3: pH levels of core sections in Jordon Pond

<table>
<thead>
<tr>
<th>Core</th>
<th>Section A</th>
<th>Section B</th>
<th>Section C</th>
<th>Section D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.8</td>
<td>5.2</td>
<td>5.7</td>
<td>5.2</td>
</tr>
<tr>
<td>2</td>
<td>4.4</td>
<td>5.0</td>
<td>5.1</td>
<td>5.5</td>
</tr>
<tr>
<td>3</td>
<td>5.4</td>
<td>5.5</td>
<td>5.6</td>
<td>5.4</td>
</tr>
<tr>
<td>4</td>
<td>5.4</td>
<td>5.5</td>
<td>5.1</td>
<td>5.6</td>
</tr>
</tbody>
</table>

The second test performed on the sediment was Rhode Island’s Pollutant 13, for the 13 most commonly occurring trace metals in the sediment. These included Antimony, Arsenic, Beryllium, Cadmium, Chromium, Copper, Lead, Nickel, Selenium, Silver, Thallium, Zinc and Mercury (Sb, As, Be, Cd, Cr, Cu, Pb, Ni, Se, Ag, Tl, Zn and Hg) respectively. The purpose of this test was to examine any possible trace metals with a high count within the study area. These core samples were analyzed from Trace Priority Pollutant (13) Metals in Soil 6010B[3000]. With the detection threshold set at the lowest possible, only six metals were present: Beryllium, Chromium, Copper, Lead, Nickel and Zinc. Out of the six trace metals detected, only Copper, Lead and Zinc will be discussed since the others did not significantly exceed the threshold.

The third test performed was for pesticides following the guidelines of the EPA 8081 test. The purpose of this test was to determine whether pesticide use today in nearby residential areas contributed to the contamination of the neighboring mill ponds. Results for both mill ponds indicate that current pesticide levels fall below the laboratory control detection limits, and so no further inference could be made. It should be noted, however, that even though no detection limit was present with this study, it is important to examine
sediment again in future testing. However, laboratory report notes indicate that insufficient sample volumes were provided for sample re-analysis, so that retesting could not be performed.

**Trace Metal Findings**

Soil sediments contain traces of different metals found within the earth’s crust, providing a normal range of background levels. Throughout the mill era most of the wastes produced by dyeing and printing textiles were organic in nature. Many of the dyes included madder (red dye), logwood (black or brown dye) and peachwood (Steinberg, 1991). Bearing these factors in mind, results through the mill era may not be as high as originally expected. Long-term human occupancy and activity tend to elevate the concentration of Chromium, Copper, Lead, Nickel and Zinc (Cr, Cu, Pb, Ni, Zn) in the soil to levels high enough to be considered contaminated. It is important to note that many of these metals are vital for proper plant and animal function at appropriate levels (Dixon, 1998).

Copper is a reddish metal that occurs naturally in rock, soil, sediment, water and air. The average concentration in the earth’s crust is about 50 parts copper per million parts soil (EBI - Copper, 2007). Copper concentrations in Peabody cores ranged from a high of 27 parts per million (ppm) to a low of 3.9 ppm (Figure 9). It is interesting to note that core 3 from Jordon Pond by the way of comparison, in Jordon Pond into which no mill activity drained, a U shape cure (Figure 10) was observed. This is indicative of spikes of copper in the oldest and newest sediment sections. The three remaining cores
showed an increase in copper concentrations from section B to section A. Levels ranged from not being detected to a high of 32ppm, which is five ppm higher than the highest level in Peabody Pond.

In terms of zinc, levels increased over time from 18 to 150ppm. In Peabody Pond, section D (the oldest sediment) of all cores had a zinc concentration between 30-39ppm. Three of the cores showed an increase in zinc in the second oldest section (section C) of sediment. For the most part Jordon Pond showed a natural increase of zinc levels over time, with much more variability than the Peabody cores. Only one core showed a major spike in the older sections of core than dropped off until the recent spike within section A. For Jordon Pond zinc levels in cores ranged from 1.6 to 200 ppm, with one core having a concentration of 50 more pp, than that of the highest Peabody Pond value. Similarly, the lowest concentration found in Jordon was almost 17ppm less than Peabody.
Figure 9: Analysis of trace metal counts (in ppm) of four cores extracted from Peabody Pond.
FIGURE 10: Analysis of trace metal counts (in ppm) of four cores extracted from Jordon Pond.

Core analysis revealed that the upper two sections (sections A and B) have the highest lead concentration compared to the older sections, which ranged from 11 to 180 ppm in Peabody Pond. However, the U-shape curve which indicated that both the oldest and newest section of the core had lead concentrations above 130 ppm, which could actually show a trend of pollution during mill activity as well as present day use. Jordon Pond levels were twice those in Peabody Pond.
Discussion

The area surrounding Peabody Pond is primarily forested, with residential settlements along the outskirts of the area, whereas forests are found on one side of Jordon Pond with residential areas and roadways on the other. Unlike Jordon Pond, the absence of human development near Peabody Pond suggests that the recent spikes of trace metals may be due to runoff or downward stream migration from Jordon Pond. Despite variations in the magnitude of road traffic and maintenance observed in the present scale of the study, many of the current findings echo those of the Legret and Pagotto (1999) who evaluated the pollutant loadings in the runoff waters from a major rural highway. For example the Legret and Pagotto (1999) study found that of the three trace metal studied, lead and zinc had the highest concentrations, with the casual factors being attributed to the sources in deicing agents on highways, corrosion of safety fences and vehicle wear brake linings and tires. Legret and Pagotto (1999) also determined air deposition to be a contributor.

Trace Metals: Copper, Zinc and Lead and pH analysis

Copper can be released into the environment by both natural sources and human activities. It can become airborne through the burning of fossil fuels, along with windblown dust, decaying vegetation, forest fires and sea spray (Lenntech, 2007). Once airborne, copper can remain in suspension until it rains out onto soil and into water. With
the present human activity of burning fossil fuels, these locations will continue to gather sediment, thus continuing to add to the final sediment analysis.

For Peabody Pond, trace metal analysis of copper did not yield conclusive results about the influence of mill activity versus present day effects (Figure 9). Two of the cores show higher concentration in the older sections (sections C and D) with a decline in the more recent ones. The other two cores show the opposite pattern, with lower concentration levels of copper in the older sections and higher values today (sections A and B). This shows that no one section is responsible for the amount of copper within the cores for Peabody Pond.

One source of the copper may be the wear of brake linings (Legret and Pagotto 2003) while another could be the corroding metal already located on the landscape from the mills. However, in present day activity, copper is a widely used industrial metal whose applications include electrical wiring, plumbing and air conditioning tubing and roofing (Michels et. al 2000). More recently, copper contamination has generally occurred from the corrosion of household copper pipes, which could be more of a contributor to the trace metal counts found in Jordon Pond compared to the lower amounts in Peabody Pond. In Jordon Pond (Figure 7) cores 2 and 3, which are located close to the road and housing settlements showed much higher concentrations of copper than cores 1 and 4 taken closer to the forested area. These results echo those of Michels et. al (2000).

The varying zinc concentration levels of 18-150ppm in the Peabody Pond and 1.6-200 ppm in the Jordon Pond, could be accounted for in one of two ways. The first
would be zinc’s historical importance in rubber making. During the early to mid 1800s, there was a rubber footwear mill in production within the study area, and the rinsing process could have washed into a portion of textile wastewater. Another mill activity which could have caused an increase rise in zinc concentrations within the sediment, was the dyeing process of cotton and wool during the mid 1800s to early 1920s. Bisschops and Spanjers (2003) discussed how dyeing contributes to most of the metals found in textile waste matter including chromium, cadmium and zinc. However, the authors also go on to state the water was not only used for the dyeing process but also in the rinsing of the dyed goods, both of which could have happened during the mill era.

Three of the cores show a much higher concentration of zinc in the upper sections of A and B, than the older C and D sections. Two possible contributions to the high spike of zinc could be from the stratospheric transport from coal-fueled factories in the Midwest, or a less dangerous form of eroding rocks and dirt that contain zinc from the weather (American Zinc Association, 2007). Zinc can enter the air both from natural and human occurrences. Most zinc enters the environment as the result of human activities such as mining, purifying of zinc, lead and cadmium ores, steel production, coal burning and burning of wastes (EBI - Zinc, 2007). Airborne zinc is present mostly as fine dust particles that settle slowly by dry deposition (Haybeck, 1994) but much more quickly by wet processes (rain, snow). Another possible effect could be present day automobile use with the wear of tires along the roadways. Given that both ponds studied showed a significant jump in zinc concentrations in Section A, present day human interactions pose more of a threat to the environment than what was found in the older sediment.
Lead trace levels reveal an interesting environmental finding in both ponds studied. Oldest core sections (section C and D) values did not exceed 140 ppm, but increased markedly (sections A and B) in the present day analysis of Peabody Pond. Jordon Pond lead levels were drastically lower in the older sections of sediment, but climbed to considerably higher concentration levels in present day sediment than for Peabody Pond. According to the Rhode Island Department of Environmental Management (RIDEM), the direct exposure criteria limit for lead in residential soils is 150ppm (Table 4) which both ponds exceed. However, compared to the Safe Drinking Water Act the maximum contamination levels are much lower than set for soil (Table 5). The sediment within these ponds show that while they may be low for soil direct exposure limits, they greatly exceed the water maximum contaminant levels for all three trace metals studied which can greatly affect the drinking water.
Table 4: Rhode Island Department of Environmental Management Direct Exposure Criteria: Inorganics

<table>
<thead>
<tr>
<th>Substance</th>
<th>Residential (mg/kg)</th>
<th>Industrial/Commercial (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>10</td>
<td>820</td>
</tr>
<tr>
<td>Arsenic</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Barium</td>
<td>5,500</td>
<td>10000</td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Cadmium</td>
<td>39</td>
<td>1000</td>
</tr>
<tr>
<td>Chromium III</td>
<td>1,400</td>
<td>10000</td>
</tr>
<tr>
<td>Chromium VI</td>
<td>390</td>
<td>10000</td>
</tr>
<tr>
<td>Copper</td>
<td>3100</td>
<td>10000</td>
</tr>
<tr>
<td>Cyanide</td>
<td>200</td>
<td>10000</td>
</tr>
<tr>
<td>Lead</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>Manganese</td>
<td>390</td>
<td>10000</td>
</tr>
<tr>
<td>Mercury</td>
<td>23</td>
<td>610</td>
</tr>
<tr>
<td>Nickel</td>
<td>1000</td>
<td>10000</td>
</tr>
<tr>
<td>Selenium</td>
<td>390</td>
<td>10000</td>
</tr>
<tr>
<td>Silver</td>
<td>200</td>
<td>10000</td>
</tr>
<tr>
<td>Thallium</td>
<td>5.5</td>
<td>140</td>
</tr>
<tr>
<td>Vanadium</td>
<td>550</td>
<td>10000</td>
</tr>
<tr>
<td>Zinc</td>
<td>6000</td>
<td>10000</td>
</tr>
</tbody>
</table>

Table 5: Selected Trace Metals and their Maximum Contaminant Level (MCLs)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Parts Per Million (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>1.3</td>
</tr>
<tr>
<td>Lead</td>
<td>0.015</td>
</tr>
<tr>
<td>Zinc</td>
<td>5 **</td>
</tr>
</tbody>
</table>

*Data acquired from http://www.epa.gov/safewater/contaminants/index.html
** Zinc was not listed with inorganic list with copper and lead (National secondary drinking water regulations)

One possible contributor during the mill era was runoff from the railway tracks once located along the Peabody Pond. Some railway operations involved the use of lead arsenates for weed control along railways, grease and oil lubricants dripping from
locomotive parts and the burning of coal from the engines (Fichter, 2007). Lead contamination also results from corroding scrap metal (lead pipes or old roofing pieces), auto exhaust from leaded gas, fallout on roadsides and even old orchards due to lead arsenates that were heavily used until World War II (Dixon, 1998). Lead levels are usually higher in cities, near roadways, industries that use lead and in the soil near homes where lead paint flakes have fallen off (Yeager, 2007). The study areas are located near a moderately traveled roadway which has implications of runoff while Peabody Pond is located downstream from an abandoned mill site with lots of iron piping left throughout the landscape from which metal traces can be leached.

Bisschops and Spanjers (2003) discuss metals entering the wastewaters from mills through metal parts such as pipes, pumps and valves as possible contributors. Oxidizing and maintenance chemicals are two other possible providers of metal traces. Although lead is not used in great quantities as previously, once present in the soil it can move very slowly and high concentrations can remain for a long period of time, causing ongoing/lasting problems in some areas (Rosen, 2002). The highest trace level of lead found in the Peabody Pond was 180ppm, and Jordon Pond had the highest trace lead level overall of 350 ppm. These are above the direct exposure criteria limit by the RIDEM. With the increased incidence of automobiles and housing near the water bodies, these concentrations need to be monitored, given that above 500ppm denotes contamination, a situation best avoided and that level should not be reached.

It is interesting to note that the observed increases of copper, zinc and lead in Jordon Pond are higher than those in the Peabody Pond. Spikes in trace metals in
Peabody Pond correspond to similar spikes in Jordon Pond, although the latter were as large as twice those observed in the Peabody Pond. This suggests a very important possible downstream migration of contaminants from the Jordon Pond to the Peabody Pond.

As aforementioned, Peabody Pond sediment pH levels were 5.1-5.9 while those of the Jordon Pond were 4.4-5.8. Although the majority of the core sections exhibited a pH between 5.5 to 5.9, there is little cause for concern from an environmental standpoint since rainwater has a pH of 5.6. However, a few of the pH outliers were below 5.5, which is important from an ecosystem health standpoint given that pH 5.5 or under can result in frog eggs and tadpoles dying (USEPA, 2008). In Jordon Pond, section A (the newest) of core 2 had a pH of 4.4, which can potentially cause problems for fish reproduction or even fish mortality (Government of Canada, 2004). This current level of acidity in one core in Jordon Pond may not cause immediate alarm, but certainly warrants ongoing monitoring in the future. Acidity can be 100 times greater with a pH level of only 2 units difference (Government of Canada, 2004). If the sediment were to be disrupted, it could cause environmental problems to the aquatic life in both ponds.

Zoning laws within the Scituate Watershed prohibit lots from extending more than twenty-five feet within the area classified as the Water Resources Protection District (Town of Scituate, 2005). However, buffer zones within the area allow lots to be 150 feet from the edge of the reservoir with the stipulations of no activities that create earth disturbance, removal or cutting of vegetation and construction on the land. Although special permits can be acquired for building within the watershed, creating land use
regulations for the disposal of waste and drainage, and many guidelines for preventing soil and sediment erosion, high lead levels are still making their way into the ponds sediment contaminating the landscape even further. Even though many guidelines are still in place, more attention needs should be paid to lead and avoiding their exceeding industrial levels.

Results from both ponds have far-reaching consequences. The amount of trace metals built up in the sediment behind the Peabody Dam is not currently high enough for contamination in the local environment, but the dam is a leaky one that is slowly continuing to deteriorate. This continuous leak (1900s to present) could also have caused trace metals to be washed downstream instead of settling. The levels of trace metals within the sediment of the Peabody Pond are considered safe as of now, however, should the Jordon Pond dam break the dramatic increases in trace metal levels to values in the past 44 years would become a cause for concern. Should these trends continue, it could cause ecological challenges for the plants and animals of the region. If trace metal contaminants from the Jordon Pond were released into the Peabody Pond at a much faster rate than at present, the suggestion to remove the Peabody Dam would be revisited, and the option of preserving it would be of much greater concern.

Conclusion

This is an ambitious study that draws on many different methodologies. Landscape change often leads to unwanted pollution of the environment. Contemporary human activities on the landscape such as residential development, lawn runoff and
motorway runoff cause stresses to the environment, while during the 1800s and early 1900s rivers functioned as waste dumps. The dams and mill ponds that were created over the last two centuries influence the environment both historically and presently. In the Scituate Reservoir these dams hold back trace metals that otherwise would flow into the reservoir. However, the source of pollution appears to be largely contemporary activities, and not historical ones.

Sediment analysis of lead, zinc and copper concentrations revealed that lead is the most significant pollutant in both ponds. This is contrary to the original study expectation that both trace metals and pesticide levels would be high. Pesticide levels fell below any detection limits. Secondly the trace metal level concentrations found in Jordon Pond from the mill era are classified as of moderate concern by other studies, although their detection may have been due to insufficient sample volumes provided to the laboratory for sample reanalysis. These results suggest that while trace metals from historic mill activity do not pose a contamination threat to the current environment, the organic pollution that was associated with printing and the dyeing of textiles could be an important contributor. However, lead levels have been increasing greatly especially in the newest sediment sections in both ponds and that is causing concern. The eroding metal within the landscape will need to be closely monitored over the next few years with the recommendation of possible further coring of soils and pond sediments to ensure that the Rhode Island soil safety level value is not exceeded.

The relationship between levels of trace metals in pond sediment and human activity around Jordon Pond is of great concern in terms of metal levels in the
environment. Jordon Pond, located near residential areas displayed twice the trace metal levels observed in Peabody Pond, which is located in the forested area. Forests are known to filter contaminants in runoff. Trace metal counts in the oldest sediment sections were 2-10 times lower than present day findings in the Peabody Pond, while the Jordon Pond was even more remarkable with 350 times higher concentrations today (section A) than in the older section (D). Both ponds had cores with elevated lead levels within the sediment. These results can be used to determine whether other ponds within the watershed in similar locations might be identified with high trace metal counts as well. At present, study results suggest that given the amount of trace metals found in the Jordon Pond and further downstream, the dam on Peabody Pond should be repaired. Since 1917, surveyors have classified Peabody dam as leaky, and it is slowly continuing to deteriorate. Due to the high lead concentrations in both ponds exceeding residential soil criteria limits, if the ponds were dredged it could affect the drinking water in the Scituate Reservoir. Action needs to be taken to repair Peabody’s dam before it is too late to avoid potential environmental problems.

This thesis contributes to geography in the realm of environmental geography. It serves as a baseline for the Providence Water Supply Board in calculating areas within their watershed, especially those near residential areas, from which to limit runoff into their ponds. Along with the georeferenced-digitized data, the Water Board can use the aerial photos to show the change in the landscape from 1939 to 2004 and prepare for the future. The Rhode Island EPA can use concentration levels of trace metals found in both
ponds to determine how much road maintenance and deicing agents are stressing the environment due to runoff and whether restrictions are necessary.

This study’s data provide a fundamental basis for the analysis of the other mill ponds in Rhode Island with existing mill remnants. They will help to establish criteria for future testing. There needs to be continuous testing of trace metals in both the Peabody and Jordon Ponds. There is a clear trend between the amount of proximate housing and increased amounts of copper, lead and zinc in the sediment at the Jordon Pond, probably due to runoff. Even though the area around the Scituate reservoir is primarily forested with no major construction within the watershed, the Providence Water Board should assess land use change as it influences surface runoff and the accumulative of contaminants in both water bodies and sediment. This is primarily a case study of the textile industry. It does not attempt to address the wide range of manufacturing process that existed at the time. However, it does suggest a new area of much needed future study.

Limitations and Future Study

This study draws on many different methodologies, and because of this no one area can be researched more in-depth. One limitation to this project was not having a timeline associated with the cores. An independent dating technique such as carbon 14 or isotope analysis should be applied to future research of sediment cores analysis of these mill ponds. With no timeline to base these findings on, one can not assume a certain depth of soil is linked to a particular time frame.
Another limitation of this study was the need for more in-depth analysis of the manufacturing process in New England. Few studies to date have compared the relationship between mill factories. Manufacturing processes differed from mill to mill, along with water power practices. With these differences, depending on the mills, each mill pond could contain very different sediment concentrations. Once information is gathered about the New England manufacturing process, it can open the door to a new field of study.

A major limitation of this project was the lack of funding for the coring. Four cores did not provide sufficient data to accurately determine whether the Peabody Pond contains highly contaminated sediment, and whether the major source of that contamination were the former mills. The existing cores have shown that there is a gradually increasing trend over time in the level of trace metals, but improved results may have been obtained by having more cores spatially distributed out throughout the pond as well as up the river to the mills themselves. The uneven spatial distribution of contamination in the sediment is another reason for further coring. This would mitigate against the occasional spikes of trace metals and pH levels observed in the existing cores from both ponds. Expanded coring would provide a more comprehensive overview of trace metals presence in the sediment, prior to taking action. Including flora/fauna testing to view a possible contaminated ecosystem and coring of soil around residential areas will help encompass more of the area instead of just the sediment that was analyzed.

Given the paucity of studies focusing on Historical Mill Pond analysis, this present study can provide much needed information for future research, by establishing
baselines for comparing sediment findings to direct exposure criteria, trace metal levels and pH values.
LITERATURE CITED

A barrage of criticism. (2000). The Economist, November 18, pp. 94-96


A barrage of criticism. (2000). *The Economist*, November 18, pp. 94-96


United States Census Bureau & RI Statewide Planning. (2000). *New England population*


