Fall 2009

Tracking bacterial pollution in the Cains Brook/Mill Creek watershed: Implications for policy and management

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TRACKING BACTERIAL POLLUTION IN THE CAINS BROOK/MILL CREEK WATERSHED: IMPLICATIONS FOR POLICY AND MANAGEMENT

BY

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B.S. Cornell University, 2004

THESIS

Submitted to the University of New Hampshire
in Partial Fulfillment of
the Requirements for the Degree of

Master of Science
In
Natural Resources and the Environment: Environmental Conservation

September, 2009

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August 12, 2009

Date

DEDICATION

I dedicate this work to my grandparents, who have shown me that it is possible to live a fulfilling life no matter what our circumstances may be, that hard work is the best way to cultivate wisdom, and that love is best given without condition.

ACKNOWLEDGMENTS

The completion of this work has proven to be one of the most educational and humbling endeavors I have ever pursued. I hope that the contents herein may serve to enhance the efforts of the Cains Brook watershed restoration, even if it is in a small way. First and foremost, I must thank my advisor, Dr. Mimi Becker, for her guidance in both the technical and personal realms, and for pushing me to do my best. Special thanks also go to my committee members, Dr. Thomas Lee and Dr. Stephen Jones, who provided their expertise in the scientific process and bacteria source monitoring.

Separately, I have much appreciation for the support I received from my graduate student colleagues, as well as from other Department faculty, particularly Dr. Russell Congalton, and the ever-supportive administrative staff, especially Donna Dowal.

My entire family, but most especially my parents, instilled in me from an early age the desire to have a positive influence on the world around me, and it is with their teachings that I have grown into who I am today. I owe an inestimable debt to the ears that endured my anxious phone calls as I fought to the bitter end to finish.

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BMP	Best Management Practice
DPW	Department of Public Works
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
GIS	Geographic Information System
IDDE	Illicit Discharge Detection and Elimination
IRB	Institutional Review Board
JEL	Jackson Estuarine Lab
MOU	Memorandum of Understanding
MS4	Municipal separate storm sewer system
MST	Microbial Source Tracking
NH DES	New Hampshire Department of Environmental Services
NHDHHS	New Hampshire Department of Health & Human Services
NHEP	New Hampshire Estuaries Project
NH F&G	New Hampshire Department of Fish & Game
NOAA	National Oceanic & Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point source (of pollution)
rRNA	Ribosomal Ribonucleic Acid
RSA	Revised Statute Annotated
SCC	Seabrook Conservation Commission
TMDL	Total Daily Maximum Load
UNH	The University of New Hampshire
VRAP	Volunteer River Assessment Program
WWTF	Waste Water Treatment Facility

ABSTRACT

TRACKING BACTERIAL POLLUTION IN THE CAINS BROOK/MILL CREEK WATERSHED: IMPLICATIONS FOR POLICY AND MANAGEMENT

by

Aaron Kornbluth

University of New Hampshire, September, 2009

Pathogenic fecal bacteria present a management challenge when they contaminate surface waters used by humans. This study examined the extent to which the ongoing Cains Brook/Mill Creek watershed restoration in Seabrook, NH has successfully characterized the problem of bacterial pollution and implemented mitigation practices. Guided by the policy sciences analytical framework, this study employed a policy implementation audit reviewing relevant bacteria source tracking data, interviews and online surveys as a means to triangulate multiple data sources. Results indicate that bacteria arise from multiple sources and impairments still exist, although bacteria levels were not generally high. Management activities have likely reduced some sources, especially human-borne bacteria, but not others, and there are a variety of misperceptions regarding sources and mitigation techniques. Recommendations for future actions include enhancing bacterial source monitoring and modeling, using a larger-scale watershed-based approach to enhance cooperation and increasing outreach to dispel misperceptions.

CHAPTER I.

OVERVIEW

Waters contaminated by bacteria pose a significant health risk to the humans that use them. Whether through drinking or direct contact, small numbers of bacteria present in the water column can infect and weaken even healthy adults. While most are not harmful, bacteria such as *Escherichia coli* strain O157:H7 and *Salmonella* DT104 cost the U.S. billions in health-related and remediation dollars annually (Teplitski 2006). Such harmful bacteria originate, predominantly, from human and animal excrement and thus are said to be "fecal-borne."

In order to curb the release of fecal-borne bacteria into both surface and ground waters, the U.S. Environmental Protection Agency has established a system of Total Maximum Daily Loads that stipulates the maximum allowable input limit for any pollutant. Because monitoring for all potentially pathogenic bacteria is neither cost-effective nor feasible, *E. coli* has been designated as the candidate organism used as an indicator of other fecal pathogens in freshwater: *E. coli* is often found in human and animal fecal wastes but is not as common in other niches; it is also easier to isolate, and subsequently culture in the lab, than many other intestinal pathogens (Feng, Weagant, & Grant 2002). Using a procedure known as ribotyping, it is even possible to determine the *source species* from which *E. coli* isolates originated. This is a type of Microbial Source Tracking, which has been employed in several studies around coastal New Hampshire.

A. The Cains Brook and Mill Creek Watershed

One ribotyping study (Jones, Landry & Edwards 2005) was conducted in the Cains Brook and Mill Creek watershed (hereafter: the Cains Brook Watershed) of Seabrook, NH. The study provides various linkages between land use patterns and subsequent fecal bacterial pollution inputs. Seabrook is a coastal town that has experienced substantial development pressures in recent decades. Due to changes in both the human community and the environment, Seabrook decided to develop a comprehensive plan to first revitalize and then promote the long-term sustainability of its small, urbanized watershed. This restoration project is the first of its kind in Seabrook, and its details are inscribed in the original 2006 Cains Brook and Mill Creek Watershed Management Plan (hereafter: the Cains Brook Management Plan) as well as the updated 2009 version, which has not yet been officially adopted by the state of New Hampshire as of June 2009 and is not discussed at length in this study.

B. Research Objectives and Questions

The primary goal of this study was to identify the degree to which Cains Brook watershed restoration efforts are being implemented using present and subsequent policies and land management practices to successfully ameliorate the problem of bacterial pollution. The objectives addressed by this study are:

1. To identify how the Cains Brook Management Plan incorporates data on the sources and causes of significant bacterial pollution and intends to employ appropriate management techniques in restoration efforts;
2. To assess the degree of knowledge about the problem of bacterial pollution and methods of bacterial pollution mitigation among the parties involved;
3. To examine the inclusiveness of appropriate parties in the Cains Brook restoration and policy process; and,

4. To assess the appropriateness and effectiveness of current and future management initiatives and activities based on MST data and BMPs.

This study utilized a policy implementation audit intended to serve as supporting research for the Cains Brook watershed restoration. The project was conducted through the University of New Hampshire Department of Natural Resources and the Environment Environmental Policy Laboratory from 2007 to 2009. To date, relatively few studies have examined the extent to which regulatory and best management practices have been implemented in sourcing and then eliminating bacterial pollution.

Assessing the regulations and policies used to manage bacterial pollution involves determining whether relevant policies exist, the specific context in which they are employed, whether monitoring is taking place and whether enforcement of those policies is taking place (Radacsi 1996) and, in this study, whether the quality of the water in the Cains Brook watershed is improving. A policy audit of this type provides the means to identify the locations in the watershed where effective management has cut down on inputs and the locations where it has not. It also serves to highlight management inconsistencies so that future efforts can better target effective management practices.

C. Chapter Summary

Chapter II discusses the specific dangers of bacteria in surface waters in the Cains Brook and Mill Creek watershed as well as a history of how pathogenic microbial pollution has continued to pose a threat to human health there. It also provides a brief overview of why the Town of Seabrook decided to undertake its ongoing comprehensive watershed restoration project.

Chapter III highlights the methods that were used to obtain data for this study and how the policy sciences analytical framework was used as a guide for gathering and then interpreting that data.

Chapter IV reports the results of study inquiries as gathered through a review of relevant bacterial source tracking data and other literature, and interviews and surveys of participants involved in the watershed restoration.

Chapter V presents an analysis of the results gathered and draws conclusions about the extent to which the watershed restoration is effectively identifying and eliminating bacterial contaminants using current and subsequent policies. This chapter also provides a list of recommendations for future investments to enhance the efforts of the restoration.

CHAPTER II.

INTRODUCTION

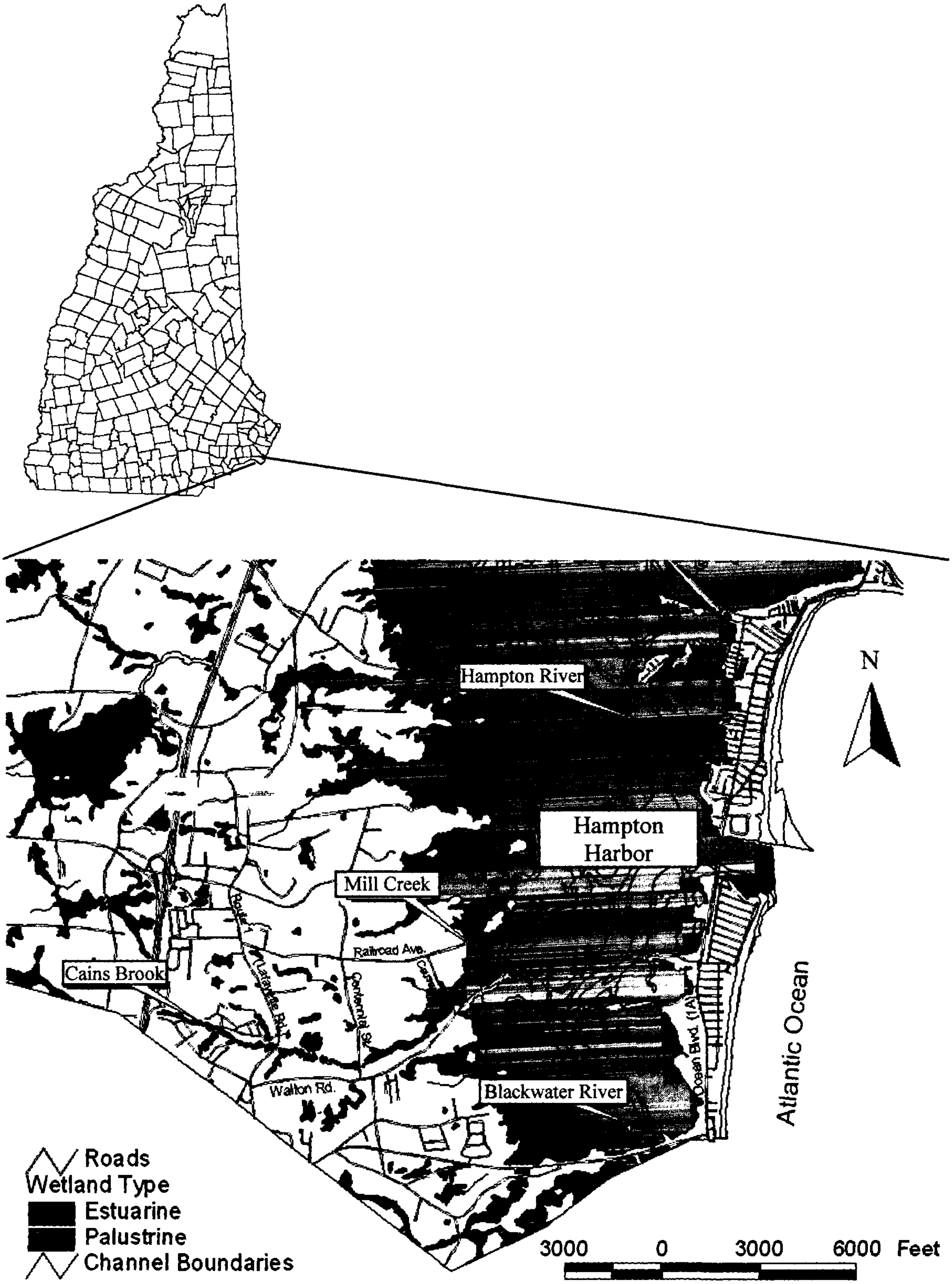
This chapter will provide information about the impacts that development can have on small coastal watersheds, the potential threat of human infection by pathogenic, water-borne fecal bacteria, potential sources of such bacteria, details about the Cains Brook watershed restoration and the studies that have been used to identify bacterial sources and causes in the watershed. It also discusses some of the impacts of the presence of fecal bacteria on shellfish beds and beaches as well as some of the relevant policies that are in place to try to limit the threat of pathogenic bacteria.

A. Study Site

Seabrook, NH (Figure 1.1) is a rapidly growing coastal town situated at the southernmost tip of New Hampshire's short 17 mile coastline, sharing it's southern border with Salisbury, MA. First settled in 1638, Seabrook has experienced intense residential, commercial and industrial growth in recent decades, a trend enhanced by the presence of U.S. Route 1 and Interstate 95 (I-95) in particular, which provide easy access to Seabrook for a growing number of tourists. Seabrook is a relatively small town at 9.6 mi^2, of which about 0.8 mi^2 (7.8%) are surface waters. Since 1970, the town has grown in population from about 3,000 residents to about 8,500 in 2007 (almost a 300% increase), ranking tenth highest in NH for population density (about 940 persons/mi^2) (NH

Economic & Labor Market Information Bureau 2008). Seabrook is a part of the larger NH coastal watershed, which includes approximately 42 towns. Within Seabrook are several sub-watersheds that drain to the Hampton/Seabrook Harbor (hereafter: Hampton Harbor), which eventually drains to the Atlantic Ocean. Perhaps the most notable of these subwatersheds is the Cains Brook watershed, which comprises about 26% of Seabrook's total area (see Figure 1.2). The watershed is named for its most dominant feature – Cains Brook – which is a first and second order freshwater stream that stretches about 3.8 miles from its headwaters west of I-95, to Centennial Street, where it becomes tidal. While most of the area of the watershed is in Seabrook (~60%), the remainder lies in Salisbury, MA (~40%). At its highest elevation of 20 ft above sea level, the headwaters of Cains Brook are mostly intermittent streams and subsurface flow just west of I-95. East of I-95, the more substantial portions of Cains Brook flow eastward through gently sloping land (on average, no more than 8% slope) to sea level, where it becomes tidally influenced (Cains Brook Management Plan 2006, 11). Mill Creek, which begins at Centennial Street, is surrounded by low and high salt marsh, and meanders into the southwestern portion of Hampton Harbor. Mill Creek is one of seven major tributaries to the Harbor (EPA 2003). In total, the Harbor is fed by some 46 mi^2 of surrounding land (NHEP 2008).

Figure 1.1. Seabrook, NH.

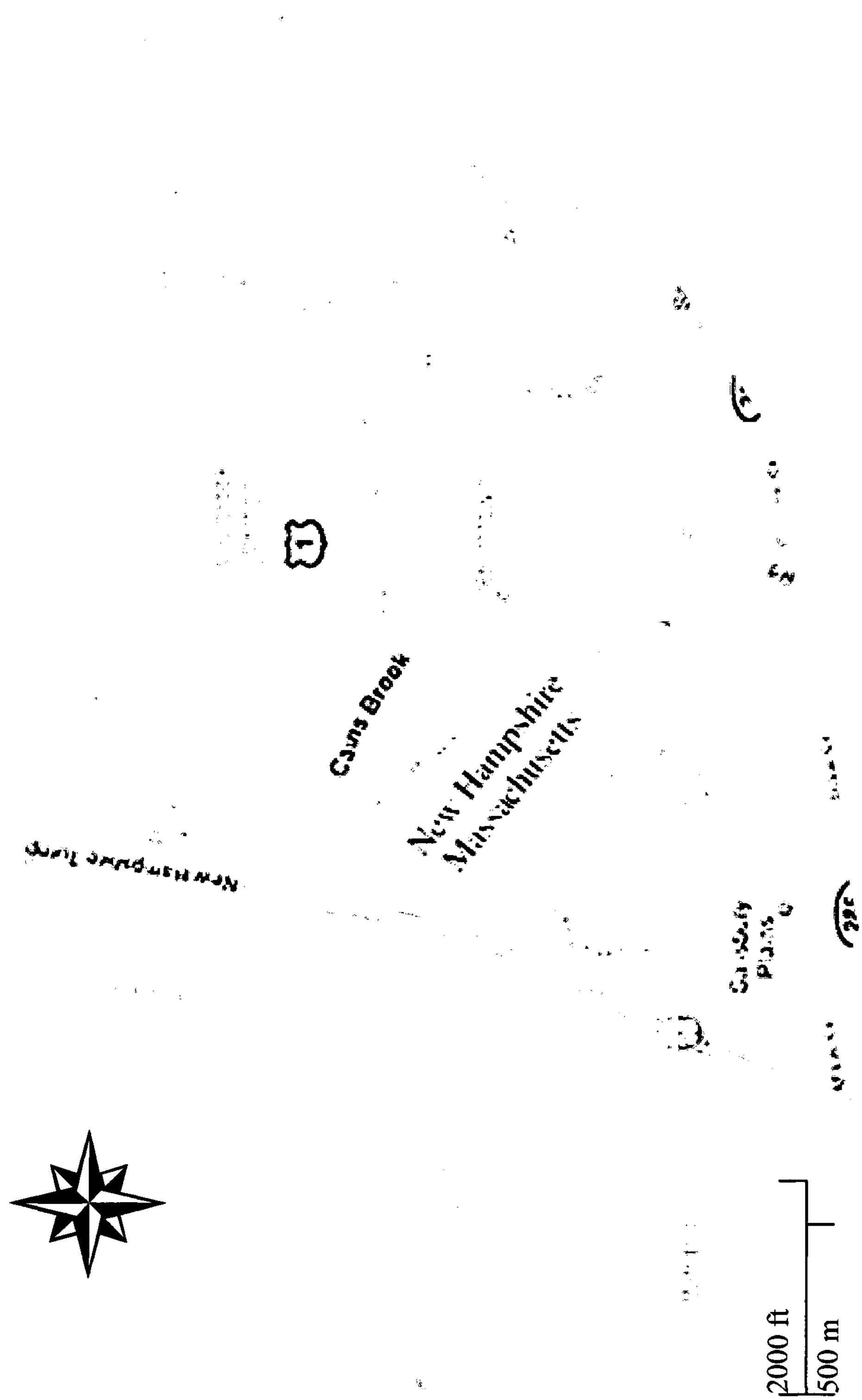


Source: NH Granit Database at: http://www.granit.unh.edu

The geology of the Cains Brook watershed is a mixture of glacial and marine sediments that overlay igneous bedrock; stratified drift soils dominate the upper portions of the watershed while fine marine sediments dominate the lower (Cains Brook Management Plan 2006). Hydric, poorly drained soils constitute the most prevalent soil type in the riparian zone on the banks of Cains Brook, and palustrine wetlands are common. The substrate of Cains Brook is primarily gravel and cobble, but finer sand and silt are also common (VRAP 2009).

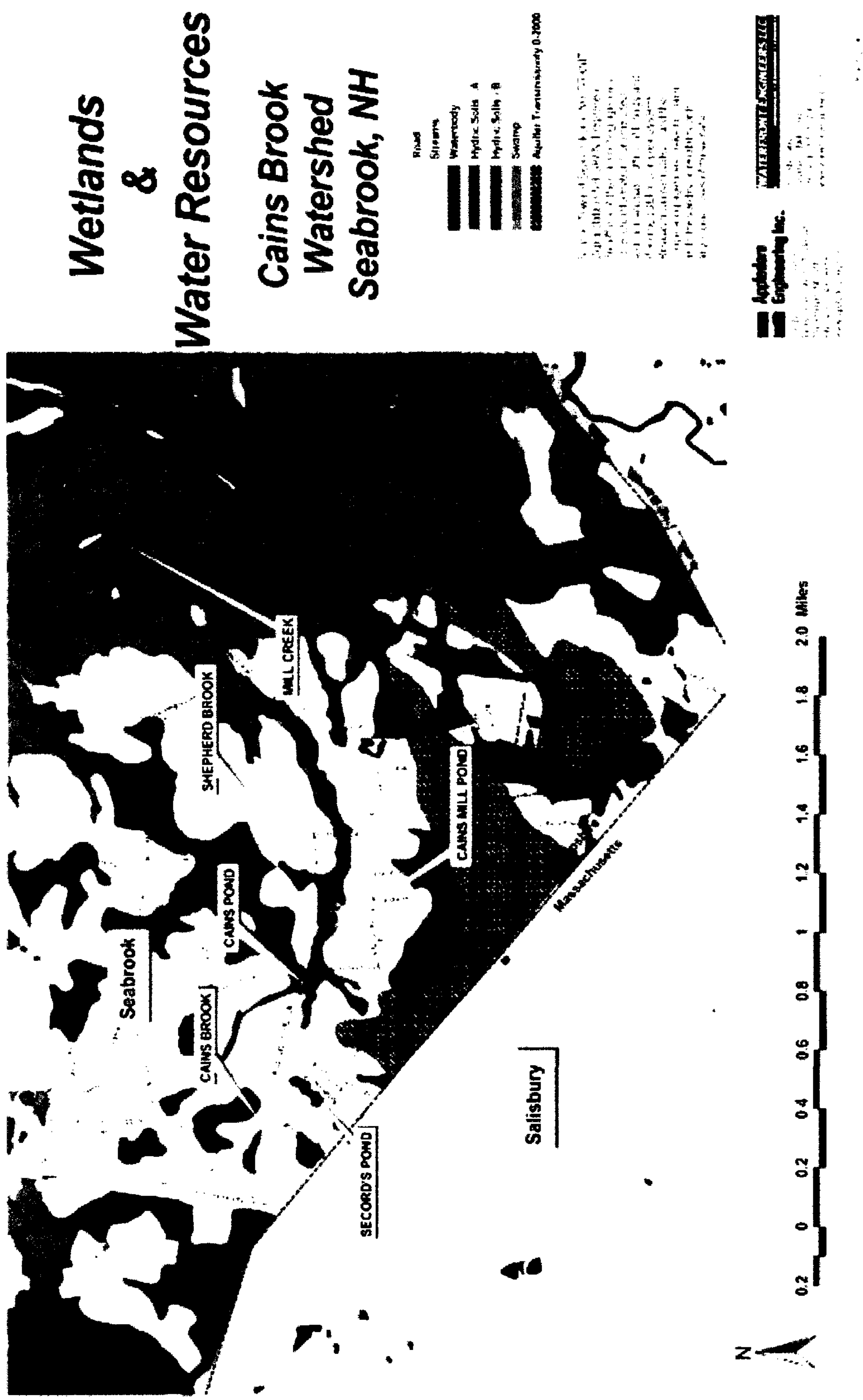
Along the reach of Cains Brook, there are five ponds that were created, via damming, to serve as either mill or ice ponds: Secord's, Cains, Cains Mill, Noyes and Mary's (Figure 1.3). They range in size from about 2 acres (Mary's Pond) to 5 acres (Cains Mill Pond). Historically, these ponds were reported to have depths around 15 ft but a variety of factors have led to their eventual filling in. The Mother's Day Storm of 2006 and the Patriot's Day Storm of 2007 contributed a substantial amount of sedimentation and debris that reduced the ponds' depths (3 pers. comm. 12/13/07). Currently, the depths of the ponds range from an average of 2-3 ft (Cains Pond) to 8-14 ft (Secord's Pond) (Cains Brook Management Plan 2006, 13).

Figure 1.2. The Cains Brook Watershed.



Source: ©2009 Google Maps; Cains Brook Management Plan 2006

Figure 1.3. Wetlands & Water Resource of the Cains Brook Watershed.



Source: Cains Brook Management Plan 2006

A variety of fish, plants and wildlife are found in the watershed, including 17 rare species of special concern and exemplary natural communities (Cains Brook Management Plan 2006, 22), according to the NH National Heritage Inventory. Biological assessments of the Brook indicate that it has a "fairly poor" biotic score (VRAP 2009). Of note, Cains Brook and its ponds once served as spawning sites for the anadromous sea run brook trout (*Salvelinus fontinalis*), which was stocked by the NH Department of Fish & Game (NH F&G) until the 1970's, but they have since disappeared (3 pers. comm. 12/13/07).

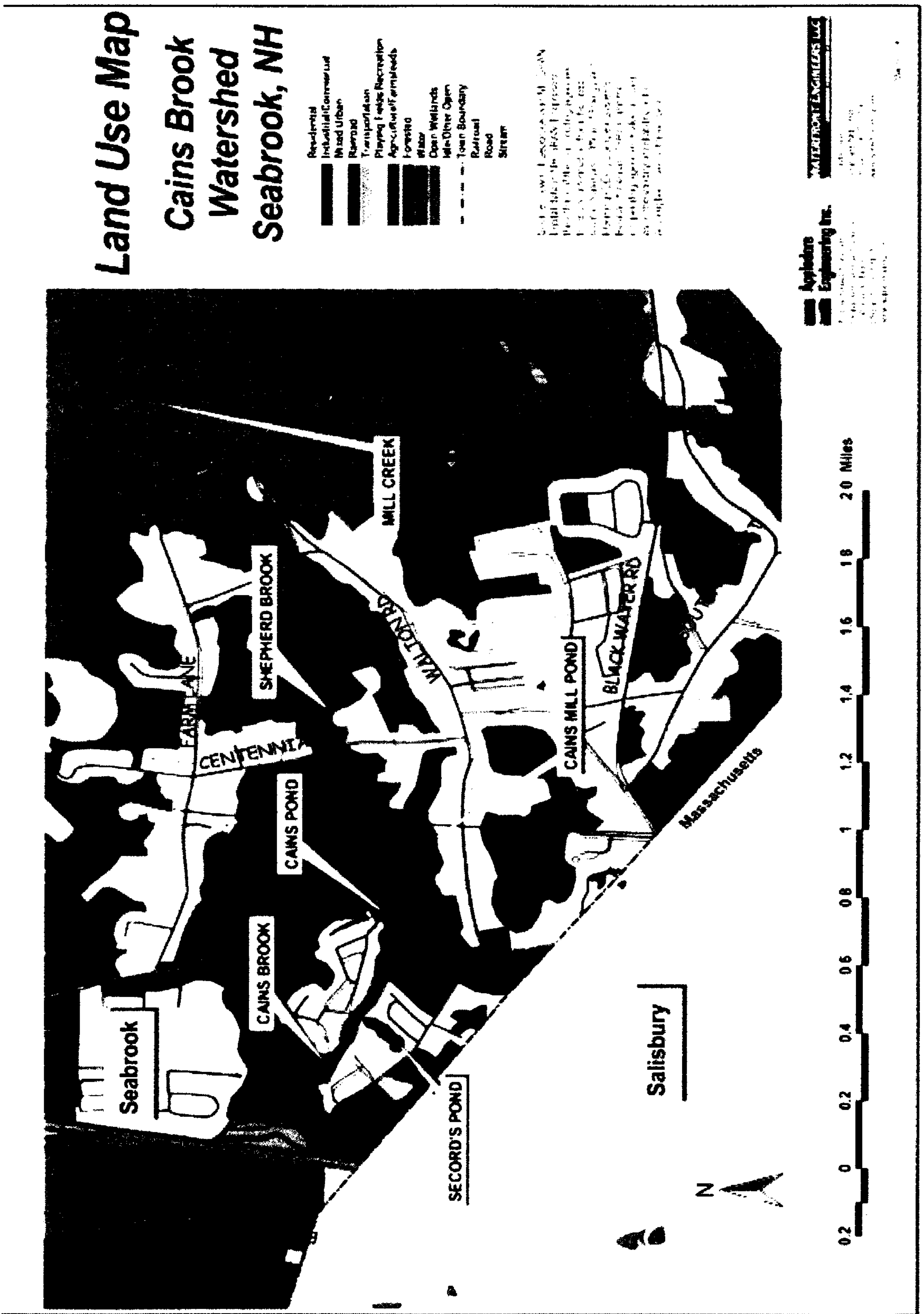
B. Industry in Seabrook

Seabrook developed around its ample water resources, both fresh and salt, which served as the backbone of its industry. Historically, it was overexploited for various natural resources. Logging, for example, was once a flourishing industry that provided pine masts for the British Navy (DeGraaf & Yamasaki 2000). Unchecked, this resource exploitation has led to a degradation of the ecological services provided by Cains Brook.

As one Seabrook Official put it, "the tsunami [of development] crested over Seabrook" (3 pers. comm. 2/11/09) as early as the 1980s. Currently, there is a mixture of different land use types found within the watershed, including residential, industrial, commercial, mixed urban, transportation, recreation, agriculture, forested, open wetlands and other surface waters (Cains Brook Management Plan 2006) (see Figure 1.4). Urbanization has been cited in numerous studies as causing substantial stream and watershed impairments. Unfortunately, there has not, to date, been any thorough synthesis of the ecological effects of urbanization on streams (Paul & Meyer 2001).

Seabrook's economy is currently driven, in large part, by tourism. As a border town, it is a popular destination for visitors from both Massachusetts and Maine, as well as other states, because New Hampshire lacks sales taxes and has relatively low gas prices. Numerous "box stores" have sprung up along the Route 1 corridor in particular, creating large areas of impervious surfaces and increasing traffic, and resultantly, pollution (Cains Brook Management Plan 2006). It is also an attractive destination for beach-goers, recreational boaters and fishers. Seabrook was considered, at one time, to be the soft shell clam (*Mya arenaria*) and clam shucking capital of the world, shipping them to New York City and even Paris, France (3 pers. comm. 12/13/07). Unfortunately for Seabrook, its clam flats are neither as healthy as they once were (NHEP 2006a), nor are they as abundant, and Mill Creek is closed year round to clamming (Cains Brook Management Plan 2006).

Figure 1.4. Land uses surrounding Cains Brook and its associated ponds.



Source: Cains Brook Management Plan 2006

Coastal areas around the world have developed at an alarmingly rapid rate as people have sought to move to coasts and as tourism to the coasts has increased, particularly to engage in water contact activities such as water sports, finfishing and shellfishing (Mallin *et al.* 2000).

Seabrook's ecosystems have been under increasing stress in the form of floral and faunal disturbances (such as declines in species abundances because of habitat loss), physical changes to the landscape and the alteration of various ecosystem services (such as reduced flood control because of altered stream channels) (Cains Brook Management Plan 2006). As of 2001, fully 31% of the Hampton Harbor drainage basin was considered developed land (which includes residential/commercial/industrial, transportation, disturbed and cleared/other lands) (NH DES 2004b, 6). NH DES has found that pollutant loadings from stormwater runoff is 2 to 14 times higher in areas of the New Hampshire coast that drain relatively high density urban areas compared to medium density single family home areas (NH DES 1999, 63). *E. coli* concentrations in stormwater from an unnamed urban site in New Hampshire were measured at an average of over 6,500 organisms/100mL while a residential site showed slightly less than 4,000 organisms/100mL in a 1996 study (NH DES 1999, 65). It is not clear whether flow rate, which is an important factor that must be considered in concert with concentration in order to understand total bacteria inputs, was also measured.

C. The Effects of Urbanization on Streams

Urbanization has resulted in numerous negative consequences on streams like Cains Brook and their associated watersheds. Such impacts are highly interconnected and should be examined in concert. It is important to note that the effects of urbanization on receiving waters is largely site-specific (Brezonik & Stadelmann 2002). What follows is a brief discussion of some of the major consequences of increased development on streams.

Floods are known to peak more rapidly (Paul & Meyer 2001) in systems where impervious surfaces, such as roads and the roofs of buildings, alter natural drainage patterns. To make matters worse, culverts, drains, swales and other flow-limiting installations can detain water during periods of high flow, especially if they are blocked (Paul & Meyer 2001). As a result of increases in impervious surface area, less water is able to infiltrate soils, a process requisite to groundwater recharge, and instead increases the amount of surface runoff. Increased sedimentation frequently occurs during urbanization: construction practices and various recreational activities contribute to erosion and loosen soils that are transported into streams during precipitation events. The result is often a change in the natural channel pattern and a filling-in of stream bottoms. Altered channel patterns can result in increased stream slopes, which in turn increase stream velocities. With decreased average stream depths resulting from sedimentation frequently come increased stream temperatures, which is an important factor that affects the growth of organisms in the water column, the benthic environment and processes such as leaf decomposition (Paul & Meyer 2001). Furthermore, streams in urbanized watersheds are generally reduced in length through alteration of basin morphometry, tending to lose their natural meanders (Paul & Meyer 2001).

In addition to the physical or hydrologic effects on streams caused by urbanization, there may be many chemical effects as well. Such impacts are largely dependent upon the type and extent of urbanization (residential versus commercial/ industrial), the presence of wastewater treatment facility (WWTF) effluent and combined sewer overflows (CSO), and the amount of stormwater drainage (Paul & Meyer 2001). Water quality constituents, such as oxygen demand, conductivity, and the amounts of nutrients and metals, are generally increased in urbanized streams (Paul & Meyer 2001).

The increased input of harmful biological agents is yet another effect of urbanization on streams, and the frequency and severity of human infection through surface waters is an increasingly common worldwide phenomenon thanks to growing populations (Geldreich 1996). Pathogenic bacteria, along with other microbial pathogens, typically occur in relatively low numbers in most waterbodies, but numerous studies have shown that urbanized streams usually have higher pathogenic bacterial densities (as indicated by the presence of indicator organisms), especially after storms, than streams whose surrounding land uses are less developed (*e.g.* de la Cretaz & Barten 2007; Hampson *et al.* 2000). A substantial portion of increased bacterial pollution can be attributed to contaminated effluent from human sources such as CSOs (Paul & Meyer 2001). High bacteria counts may also be detected during dry weather periods and can sometimes be indicative of sustained septage input due to non-functioning and/or inadequately maintained septic systems common in un-sewered areas.

Evidence shows many of the aforementioned negative impacts are present in the Cains Brook watershed (see Cains Brook Management Plan 2006; Jones, Landry & Edwards 2005; NHEP 2006a), although many still recognize that the watershed is generally healthy (Cains Brook Management Plan 2006). Areas such as the Cains Brook watershed that drain to waters used as beaches, drinking water sources or shellfish growing are considered of the highest priority for human health reasons (NH DES 2006) and so require regular monitoring as a part of the Federal Clean Water Act water classification requirements. Designated as Class B waters along with most of the water bodies in New Hampshire (under NH RSA §485-A:8 Water Pollution and Waste Disposal), these waters are not sufficient for use as drinking water, but are acceptable for uses such as swimming, other types of recreation and fish habitat.

D. The Bacterial Threat

Unlike pathogenic human viruses, which are shed only by infected individuals, pathogenic bacteria are shed into surface waters by a wide variety of animal hosts (Geldreich 1996). Most of the bacteria that occur naturally in surface waters are benign, however, and are essential to natural ecosystem processes such as decomposition. The bacteria that are free-living in surface waters rarely infect humans (Rosen 2000), at least in temperate, developed countries (Geldreich 1996). Infectious water-borne bacteria typically originate from within the intestines of organisms, and are shed in fecal matter. Even among the many fecal-borne bacteria, most do not cause outbreaks of disease (Rosen 2000).

Consumption, inhalation and physical exposure to pathogenic bacteria, if in sufficient quantities, can lead to illness, and in some cases, death in humans (Hagerdorn *et al.* 1999). A high proportion of the surface and groundwaters of the mid-Atlantic are impaired because of fecal bacterial pollution. The presence of high concentrations of such bacteria is particularly disturbing because of its threat to human health. Unlike exposure to chemical contaminants such as arsenic or benzene, which typically require long-term exposure to cause illness, bacteria are an acute health threat because they can cause illness with minimal exposure. Most fecal-borne bacteria naturally die off once outside their host within 30 days (NH DES 2008a), although other evidence suggests that bacteria, including toxigenic *E. coli*, can exhibit a maximum survival period of up to 90 days in surface waters (Geldreich 1996). The effects of dilution and water treatment have substantially limited the number of water-borne microbial infections, making contaminated food and host-to-host contamination the most common routes of transmission (Rosen 2000). Fecal borne bacteria are typically poor competitors with native bacterial flora and there are a number of factors that influence their longevity, including pH, nutrient availability, pesticides, organic matter content, temperature and exposure to the sun (Rosen 2000).

Despite the decreasing trend in water-borne infections in developed countries, there are numerous pathogenic fecal-borne bacteria that can be transmitted among organisms via surface waters, including those that cause typhoid, cholera, dysentery and enteric fever (NH DES 2001). These bacteria have been responsible for eye, ear, nose, skin, respiratory, gastrointestinal and other types of infection (Geldreich 1996; Rose *et al.* 2001). Pathogenic strains are most harmful when they: are introduced into the environment in high densities; are highly infectious; survive, reproduce and remain infectious for abnormally long periods; and, are resistant to chemical treatment. The most common indicators of fecal contamination (and thus the presence of microbial pathogens) fall into three categories: total coliform, fecal coliform and *E. coli*:

> The **total coliforms** group is commonly found in the soil and is not necessarily indicative of a threat to public health. Their presence does, however, require further testing as there should not be total coliforms present in a properly constructed/maintained water system.
>
> **Fecal coliform** bacteria fall into a subset of total coliforms, originating from the gastro-intestinal systems of animals. While they typically have a shorter lifespan outside their hosts than other coliform bacteria, their presence can indicate the improper disposal of sanitary wastes.
>
> ***E. coli*** is a member of the fecal coliform family. Its presence is highly indicative of the presence of human and animal wastes that can contain other disease-causing organisms (NH DES 2008b).

One particular strain of *E. coli* – O157:H7 – is particularly worrisome in that it produces a potentially deadly toxin that causes severe kidney and intestinal damage (Rosen 2000), and can provoke symptoms in 50% of individuals at a dose of only 10^2 organisms (Geldreich 1996, 316). It has been isolated from the feces of cattle, deer, sheep, dogs, horses, birds (including chickens) and even flies, and is most commonly transmitted through eating food or drinking liquids that are contaminated (Rosen 2000). Other bacteria that are potentially harmful to humans include *Campylobacter spp.* and *Salmonella spp.* Of secondary concern are organisms for which the water-borne route is rarely documented; they include *Yersinia spp., Brucella sp.*, and *Leptospirosis interrogans* (Rosen 2000). However, it is important to note that the majority of shellfish-borne and recreational water contact related infections in humans occur not because of exposure to pathogenic bacteria, but *viruses* instead (Beran 1994; Walsh 2008). Many human enteric viruses are considered to be rather stable in estuarine environments and some (such as the hepatitis A virus) have caused large disease outbreaks through consumption of contaminated shellfish (Beran 1994). In one particularly catastrophic outbreak, some 250,00 people were infected with hepatitis A after eating contaminated clams in 1998 (Walsh 369).

It is neither feasible nor cost-effective to test waters for the presence of each and every type of potential microbial pathogen. Therefore, indicator species are used as a proxy because there is a statistically significant chance of finding indicator bacteria in the presence of these pathogens (Geldreich 1996; NH DES 2001). The indicator bacteria are not usually infectious themselves, and are much less costly and easier to detect and source than microbial pathogens (Meays *et al.* 2004). Both *E. coli* and *enterococci* exhibit patterns closely associated with outbreaks of gastrointestinal illness to a greater degree than fecal coliforms; therefore, they are recommended by the Environmental Protection Agency (EPA) as the best indicator organism to test for the presence of other pathogens (Rosen 2000). Freshwater *E. coli* measurements can help to determine if water is safe for human use, but it is important to note that potential pathogens, such as *Cryptosporidium parvum, Shigella sp.* and *E. coli* O157:H7, may be present in water that meets all bacterial water quality standards (Geldreich 1996). This anomaly suggests the need for better indicators and detection methods (Rosen 2000).

E. Non-point Sources of Bacteria

Along with 13% of surface waters country-wide (Santo Domingo *et al.* 2005), studies show that Cains Brook and Mill Creek have not met designated use criteria, such as shellfish consumption, because of high counts of fecal bacteria (Jones, Landry & Edwards 2005; NH DES 2007a). Similar to other coastal areas, the growing utilization of Seabrook's coastal land and water resources (Cains Brook Management Plan 2006) has likely increased the possibility of aquatic-borne disease transmission to human hosts through contact with contaminated water and shellfish consumption (Mallin *et al.* 2001). While some of the contamination likely originates from singular locations, public awareness and regulatory action have substantially cut down on obvious inputs, or point sources, in the Cains Brook watershed and throughout New Hampshire (NH DES 2004a). Eighty-seven percent of the daily fecal bacteria input into Hampton Harbor has been attributed to dry-weather non-point sources (NPS), while the remaining 13% comes from boat sewage discharges; wet weather contributions arise from stormwater sources (76% of daily total input), dry-weather NPS (21%) and boats (3%) (EPA 2003). Unfortunately, it is very difficult to identify specific locational origins of NPS of bacteria. Such sources are numerous and vary substantially due to demographics, land uses and the effectiveness of enforcement and monitoring activities (Mallin *et al.* 2000). Some of the most common NPS contributions originate from:

- **Stormwater runoff**: since pollution follows the course that water takes in the hydrologic cycle, precipitation events cause particles on the ground to be suspended and washed into nearby surface waters. Stormwater runoff does not infiltrate the soil due in part to "*physical factors*, including type and intensity of land use, degree of imperviousness, tree cover, soil type, slope, and drainage density, … and *climatic factors*, such as rainfall intensity and duration, storm frequency, and time since antecedent rainfall" (Brezonik & Stadelmann 2002, 1744). "First flush" stormwater, which occurs with the first heavy rainfall following a long dry period, is noted to contain particularly high levels of contaminants (Lee *et al.* 2002). Regardless, bacteria can pose a significant threat even during dry weather (NHEP 2006a). It is important to note that stormwater runoff itself is not necessarily an indicator of how much bacteria may be entering a waterbody, but it can generally be assumed that in an urbanized watershed like Cains Brook, bacterial loading increases with increased stormwater runoff (Schillinger & Gannon 1985).

• **Impervious surfaces**: any surface that prevents water percolating naturally into the soil is classified as an impervious surface (Arnold & Gibbons 1996). Fecal material deposited on or near impervious surfaces is easily swept into surface waters as stormwaters cascade downhill. The percentage of impervious surfaces in a watershed has been linked closely to the resultant water quality, with significant biological effects being noticed when an area has 10% impervious surface or more (Mallin *et al.* 2000). In one study of two estuaries and their associated streams (similar in geography and degree of development to the Cains Brook watershed), it was shown that acceptable microbiological water quality was present in those parts of the watershed with less than 10% imperviousness, degraded water quality was present in those parts with over 10% impervious surface and severe impairment occurred over 20% impervious surface (Mallin *et al.* 2000). According to the 2006 State of the Estuaries Report, impervious surfaces are being added at a rate of 1,185 acres per year in the Greater Seacoast region of New Hampshire; average land consumption per person is also increasing (NHEP 2006a). Both of these trends are indicative of a pattern of sprawling growth. However, other studies indicate that it is the *proximity* of impervious surfaces to surface waters and stormwater management practices that may have a greater impact on water quality (NHEP 2006a). According to the 2006 New Hampshire Estuaries Project (NHEP) Environmental Indicator Report, the amount of impervious surfaces in Seabrook have increased at an even more rapid rate than the larger Hampton Harbor watershed (NHEP 2006b) (Table 1.1).

Table 1.1. Impervious Surfaces in the Hampton Harbor Watershed and Seabrook.

Impervious Surface by Acreage and *Percentage of Total Area*	**1990**	**2000**	**2005**
Hampton Harbor Watershed	1529 *(10.8%)*	2163 *(15.3%)*	2519 *(17.8%)*
Town of Seabrook	801 *(14.1%)*	1206 *(21.3%)*	1539 *(27.1%)*

Source: NHEP 2006b

Clearly, the rapid rate of development in Seabrook has led to a dramatic increase in total impervious surface area, well beyond the 20% threshold deemed to cause severe impairment to water quality (as noted in red for 2000 & 2005).

• **Failing septic systems**: old, leaky and broken septic systems can provide a constant source of bacterial contamination (Geldreich 1996). This source of bacteria is exacerbated due to the fact that leakages may go unseen for many years because of poor maintenance, or a lack of maintenance. Since the most common means of infection by water-borne bacteria is exposure to human sewage rather than agriculture or wildlife (Rosen 2000), this is a particularly important bacterial origin. Fortunately for Seabrook, 99% of the Town is currently serviced by municipal sewer (3 pers. comm. 12/30/07), limiting the amount of private, unmonitored, and potentially leaky septic systems. However, the situation is complicated by the fact that the portion of Salisbury, MA that lies within the headwaters of Cains Brook is not serviced by municipal sewer, but instead relies on subsurface disposal systems for treating wastewater (NH DES 2007a). Unless they are properly maintained, these systems have the potential to contribute bacterial pollution to the lower reaches of Cains Brook, and ultimately, Hampton Harbor.

• **Inadequate/Failing/Poorly Maintained WWTFs**: although WWTFs are considered as point sources, as opposed to non-point sources, of pollution, they are included here because they represent a significant potential contributor of fecal pathogens. Insufficiently processed sewage can seep or overflow from WWTFs (Geldreich 1996), especially during periods of heavy rainfall that overburdens these systems. Throughout the New Hampshire Seacoast, WWTF upgrades and the removal of sewage inputs from stormwater sewer systems have likely contributed to a decline in bacteria found in surface waters (NHEP 2006a). However, as recently as 2004, the EPA filed suit (an EPA formal enforcement action) against the Town of Seabrook for violations of the city's water discharge permit (Fleming 2004), issuing a $31,000 fine under the Clean Water Act (§301/401) (www.epa-echo.gov ID Number: 110006619622). The violations occurred from 1999-2003, and included permit exceedances of fecal coliform bacteria and inadequate operation and maintenance of the treatment facility under the National Pollutant Discharge Elimination System (NPDES), which sets standards that govern the release of potential contaminants from WWTFs and storm sewer systems. It is important to note that industrial, commercial and municipal facilities must obtain NPDES permits for discharges into surface waters (but private residences connected to a municipal sewer or using on-site septic systems need not obtain permits). The Seabrook WWTF outfall pipe conveys the facility's effluent to the Atlantic Ocean (see Figure 4.1), where the prevailing north-to-south currents are likely to carry that effluent away from both Seabrook and the Hampton Harbor (S. Jones pers. comm. 8/20/09).

• **Cross-connections between sanitary sewer and stormwater systems (CSO) and Storm sewer overflows (SSO)**: these types of inputs occur when sanitary and/or storm sewers are misconnected or overburden storm drainage systems, permitting the discharge of untreated effluent and/or potentially contaminated stormwater. It is estimated that CSOs and other wet weather pollution sources such as stormwater runoff cause approximately half of all U.S. estuary contamination (Rose *et al.* 2001). There are some coastal sewer systems throughout coastal New Hampshire that have insufficient capacity to contain effluent during period of heavy rainfall, which can result in significant bacterial loading (Jones 2001).

• **Overboard boat toilet discharges**: navigation of the waterbodies of the Cains Brook watershed is limited to kayaks, canoes and small row boats due to limited size. However, larger boats and jet skis are found in Hampton Harbor and even Mill Creek (3 pers. comm. 2/11/09). It is possible, although poorly studied, that the currents of the incoming tide could transport bacteria from this source upstream into Mill Creek (1 pers. comm. 11/30/07).

• **Livestock and pets**: livestock and pets can contribute significant bacterial loading into waterbodies. There are limited numbers of livestock present in the urbanized Cains Brook watershed, but it is not uncommon to find chickens, geese and horses

(Jones, Landry & Edwards 2005). While Seabrook does have a "Pooper Scooper" Ordinance (Section 152-13: Animal Waste) that requires immediate removal of pet wastes, controlling bacterial contamination from these sources is a problematic management undertaking because it necessitates vigilant enforcement and, more importantly, responsible citizens.

• **Wildlife**: wild animals, while difficult to manage, can contribute fecal bacteria to water bodies (Geldreich 1996; Nelson *et al.* 2008). Development pressures may preclude some types of wildlife, but much of the Cains Brook corridor is still forested, providing habitat and forage for Canadian geese and other waterfowl, deer and other small mammals.

• **Re-suspension of contaminated sediment**: Research has shown that fecal contaminant indicator bacteria have been found in association with suspended sediments that were previously contaminated; this is troubling, in part, because fecal bacteria survive for significantly longer periods when associated with sediment particles (Mallin *et al.* 2000; Burton, Gunnison & Lanza 1987). In addition, extended survival of bacteria that are associated with sediment can make proper source identification more difficult (Howell, Coyne & Cornelius 1996). Construction practices and other land uses in an urbanized watershed contribute increased sediment loads that can be associated with other forms of pollution containing fecal bacteria. In Seabrook, where summer construction is common, this may be a critical source of sediment input.

• **Litter/Trash**: bacteria thrive on human-generated trash, especially when it includes organic matter that can serve as a food source. Common "bacteria fodder" found in trash includes, but is not limited to, food debris and leftovers, used baby diapers, and pet feces. The direct input of litter, both intentional and unintentional, is not an uncommon occurrence along Cains Brook. The quantity of litter-borne bacterial food sources is exacerbated, however, by the presence of large areas of impervious surfaces throughout the Route 1 corridor and elsewhere. Wild animals, especially gulls, are attracted to sources of bacteria that include untreated sewage, garbage dumps and manure, and have been known to transport enteric pathogens in high quantities in their fecal matter (Nelson *et al.* 2008). Human-generated trash is noticeable in and around Cains Brook and its associated ponds throughout much of the watershed, but is particularly common in areas with large areas of impervious surface (Cains Brook Management Plan 2006; Site Walk 5/4/09).

• **Manure**: soils that are supplemented for nutrients using manure-based fertilizers can be suspended in surface runoff, contributing bacteria to nearby waterbodies and providing additional organic matter for consumption (Geldreich 1996; Shelton *et al.* 2003). The body of literature available on microbial leaching through soils is extensive, with most studies illustrating that transport is dependent upon soil or sediment texture and permeability, water saturation degree, and length of time (Shelton *et al.* 2003). In addition to manure spread on residential gardens or agricultural lands, manure in large outdoor commercial storage yards can potentially leach live bacteria during rainfall (3 pers. comm. 12/13/07). Fortunately, the treatment of manure via composting, drying and storage before application can significantly reduce the quantity of bacteria entering surface waters (Geldreich 1996).

• **Natural occurrence in soils**: fecal-borne bacteria are found in soils where organisms deposit fecal matter both on the surface and below (Geldreich 1996). Concentrations of potentially harmful bacteria vary depending on temperature, soil composition, presence and density of animals and nutrient sources, and other factors. Naturally occurring soil bacteria are very difficult to manage.

These numerous sources of potentially pathogenic fecal bacteria (and other microbial pathogens) present significant management complications. Despite the investment of considerable resources throughout the New Hampshire coastal watershed, fecal contamination remains a high priority target and is the primary reason why shellfish beds are closed to harvesting (NHEP 2006a; Jones 2001). Human pathogens have even been found in shellfish in the absence of human illness, and may be naturally occurring in growing areas (FDA 2007).

F. Shellfish Bed Closures

Pathogenic bacteria pose a serious threat to human health through the consumption of shellfish because filter-feeding mollusks accumulate and concentrate bacteria in their tissues. Serious illnesses can occur, especially among immuno-compromised individuals and youths, as a result of the consumption of pathogen-laden shellfish. Hampton Harbor is one of New Hampshire's largest shellfish growing areas (5 pers. comm. 12/20/07) and its most popular clam harvesting area (Jones & Landry 2003), which denotes the critical need to minimize the threat of infection there.

Public health experts and other officials are charged with setting water quality standards that stipulate the maximum concentrations allowed for drinking water, primary contact recreation and consumption of fish and shellfish. These EPA-established Total Daily Maximum Loads (TMDLs) are established under section 303(d) of the Clean Water Act and the Water Quality Planning Regulations (40 CFR Part 130). The TMDL process sets quantitative limitations on the total allowable pollutant load per day for waterbodies based on pollutant sources and water quality (EPA 2003; NH DES 2004b). This process provides states with the authority to establish mechanisms to control and reduce pollution from both point and non-point sources. In New Hampshire, the TMDLs for bacteria are divided among three designated uses (Table 1.2).

Table 1.2. Bacterial Indicator Standards for Surface Water Classification.

Designation	**Classification**	**Indicator Used**	**Geometric Mean***	**Maximum Concentration***
Freshwater	Class A	*E. coli*	47	153
FW designated beach	Class A	*E. coli*	47	88
Freshwater	Class B	*E. coli*	126	406
FW designated beach	Class B	*E. coli*	47	88
Tidal Recreational		*Enterococci*	35	104
Shellfish-growing	Approved	Fecal coliforms	14	>43
	Restricted	Fecal coliforms	14-88	>260
	Prohibited	Fecal coliforms	>88	
				*Concentrations per 100mL

Source: NH RSA §485-A:8:V Water Pollution And Waste Disposal

The news is troubling that the TMDL for Hampton Harbor indicates that Mill Creek, among its many tributaries, contributed the highest bacteria counts measured in the Harbor (EPA 2003; NH DES 2007a); in fact, the sampling station at the mouth of Mill Creek is the *only* station that exceeded the geometric mean standard (EPA 2003). Therefore, bacteria loading in the Cains Brook watershed is likely the main reason why shellfish beds are closed to harvesting in the once-plentiful clam flats (NHEP 2006a).

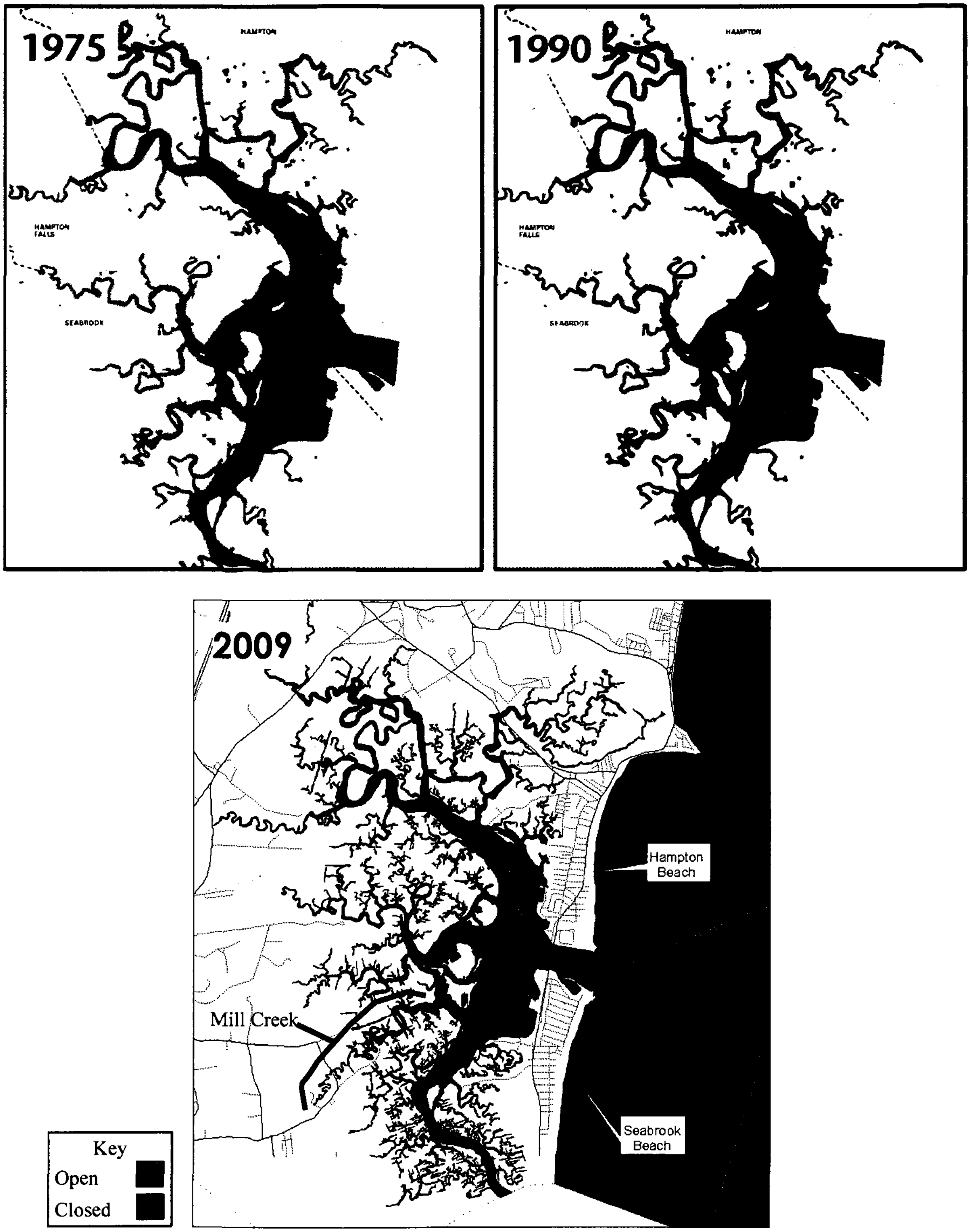
While Mill Creek has always been closed and other areas of the Hampton Harbor have been subject to closures in the last few decades, the extent of closures has decreased since 1990 (Figure 1.5). Shellfish bed closures can occur due to:

- Rainfall events that flush significant amounts of pollutants into waterbodies;
- Accidental releases of untreated sewage and/or hazardous materials;
- Beds located near WWTFs are permanently closed;
- If no sanitary survey is conducted as part of the TMDL process in three years, the beds will be closed;
- If no sanitary survey has been ever conducted, beds will be closed and categorized as unclassified;
- The presence of red tide pathogens that cause Paralytic Shellfish Poisoning;
- Some beds are closed for resource conservation during the summer; and,
- Chronic exceedances of standards will result in closures.

(NH DES Shellfish Program Online FAQs – Shellfish Closures 2009 at: http://des.nh. gov/organization/divisions/water/wmb/shellfish/categories/faq.htm; Jones & Landry 2003).

In New Hampshire, rainfall events frequently result in the closure of shellfish beds, although the amount of rainfall needed to cause a closure differs by location. All shellfish beds are closed throughout New Hampshire following major storm events (Jones & Langan 1996), but Hampton Harbor closures occur following rain events of 1/2 inch or more within a 24-hour period in November, April and May; the limit is 1/4 inch during December through March (NH DES 1999, 66). Shellfish beds remain closed until there has been sufficient time and flushing of pollutants to occur and the shellfish have sufficiently reduced their levels of contaminants. This period is typically 14 days after a rainfall event, but can be sooner if tissue samples reveal that the shellfish are safe to eat.

Figure 1.5. Status of Shellfishing in the Hampton Harbor Watershed, 1975 to 2009.

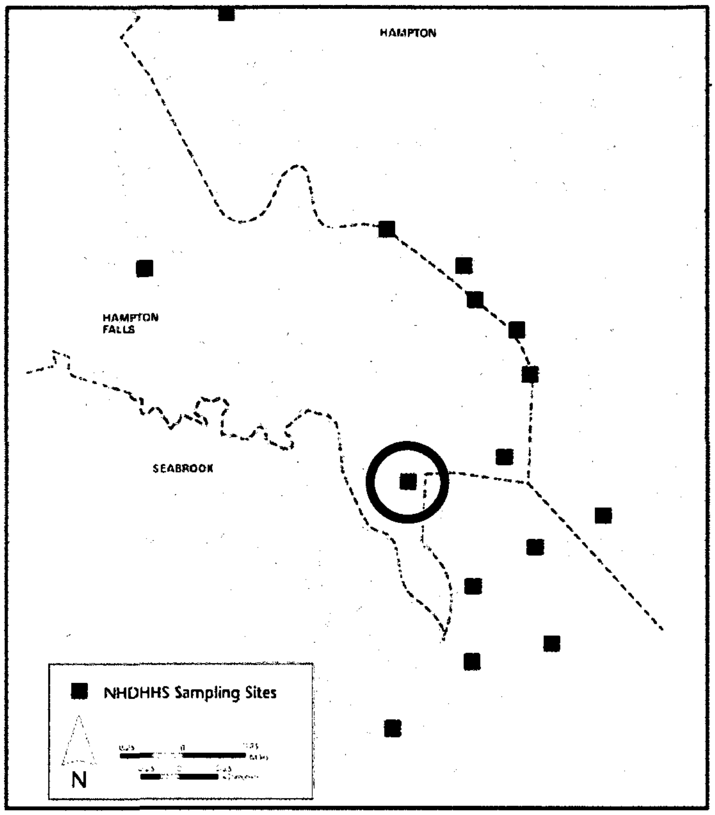


Source: NH DES Shellfish Program Online Shellfish Classification Map (2009) at: http://des.nh.gov/organization/divisions/water/wmb/shellfish/hampton_seabrook.htm; Jones 2001.

The water quality of economically-important shellfishing areas, including the Hampton Harbor, is typically sampled by the New Hampshire Department of Environmental Services (NH DES) Shellfish Program, which is the state arm of the National Shellfish Sanitation Program administered by the Food and Drug Administration (FDA). The NH DES Volunteer River Assessment Program (VRAP) assists the Shellfish Program with sampling each site six to twelve times per year for fecal coliforms and salinity. In order for a shellfish growing area to be declared open ("approved" or "conditionally approved"), a comprehensive sanitary survey is conducted, examining the shoreline, the effects of any meteorological, hydrodynamic, and geographic characteristics on the growing area, and the bacteriological quality of the water (FDA 2007). Such sanitary surveys are conducted at minimum of every 12 years, but updated annually to reflect changes in growing area conditions. Conditionally approved growing areas in proximity to WWTFs, CSOs or other point sources must be monitored monthly, while a minimum of six samples must be taken when non-point source inputs (rainfall events, stormwater runoff, seasonal variations) are present (FDA 2007).

The New Hampshire Department of Health and Human Services (NHDHHS), in cooperation with NH DES and New Hampshire Fish & Game (NH F&G), monitor shellfish bacteria concentrations, and will take tissue samples after periods of rainfall (as described above) at about 15 locations throughout the Harbor (Figure 1.6), which is divided into 14 units that are characterized as restricted, prohibited/unclassified, prohibited/safety zone or conditionally approved (NH DES 2004b). Notice that the site (circled) closest to the mouth of Mill Creek has been consistently cited as having higher bacterial concentrations (Jones 2001).

Figure 1.6. Shellfish Monitoring Sampling Sites in Hampton Harbor.



Source: Jones 2001

Studies in other regions have demonstrated that increased development pressures are positively associated with increased closures of shellfish beds due to bacterial pollution (Mallin *et al.* 2000). These closures have been linked to significant economic consequences to communities (Mallin *et al.* 2000). To date, there have not been any studies examining the total lost economic value that has resulted from closures due to bacterial pollution in the Hampton/Seabrook Harbor watershed, including Mill Creek.

G. Beach Closures

There is a strong relationship between the incidence of gastroenteritis among swimmers and counts of marine enterococci and *E. coli* (Rose *et al.* 2001). Since Mill Creek has been shown to contribute the highest bacterial counts among all of the tributaries to Hampton Harbor, there is a risk that bacterial pollution from the Cains Brook watershed may contribute to the recent increase in tidal beach advisories. Before 2003, there were no tidal beach advisories for the entire NH seacoast, but there were ten advisories during the 2003-05 bathing seasons (Jones *et al.* 2004; 2). However, during the 2006, 2007 and 2008 summer sampling seasons, there were no beach advisories caused by elevated bacteria levels at the Seabrook, Seabrook Harbor or Hampton Harbor beaches (NH DES 2007b; NH DES 2007c; NH DES 2008c; NH DES 2008d; NH DES 2008e; NH DES 2009b; NH DES 2009c; NH DES 2009d). Regardless, it is important to continually monitor the beaches within Hampton Harbor as well as the Hampton and Seabrook beaches because of the high potential for infection by pathogens. With as many as 150,000 potential visitors at Hampton Beach on a summer Saturday (Long 2009), the risk of an outbreak of fecal-borne bacteria is ever present.

H. Beginning Remediation

Seabrook's history is defined by the occupational and recreational opportunities provided by its water resources. Generations of "Seabrookers," as they are affectionately known, have dipped for alewife fish (*Alosa pseudoharengus*) as a food source, cut ice in the winter that would be shipped to Boston and Portland, and used the Brook for milling (3 pers. comm. 2/11/09). Despite its pastoral roots, conflicts have arisen among user groups – residents, businesses, officials, and tourists – in this small urban watershed. It is all too easy for one user group to identify others as being the cause of pollution without a sound, scientific basis (Meays *et al.* 2004). However, health concerns regarding exposure to pathogens can serve to unify restoration efforts and minimize human conflict. Fecal-borne bacteria can be reduced to safe levels through ecologically sound land use planning and development policies and activities (Mallin *et al.* 2000), the most critical of which should aim to minimize the numbers of microorganisms that reach ground and surface waters, and thereby avoid significant contamination (Rosen 2000). Employing the use of prescribed Best Management Practices (BMP) to control non-point sources of pollution can take the form of structural and non-structural applications, but the identification of the *best* BMP is often subjective and based on nearby land uses (NH DES 2004a).

Growing concerns over water quality issues and the loss of aquatic habitat in the Cains Brook watershed led Seabrook to conduct the first of several watershed-scale studies in 1997. These studies have been conducted to assist in sourcing and then eliminating water quality threats to human health throughout the watershed:

- Impact of Septic Tank Disconnections on Water Quality in Coastal Surface and Subsurface Environments—1997
- Cains Brook and Mill Creek Watershed Study—1997
- Tracking Bacterial Pollution Sources in Hampton Harbor—2003
- Total Maximum Daily Load (TMDL) Study for Bacteria for Hampton/Seabrook Harbor—2003
- Tracking Bacterial Pollution Sources in Cains Brook/Mill Creek Watersheds—2004

These studies consistently indicated that bacterial pollution is present in sufficient amounts to pose a threat through primary contact recreation and consumption of shellfish. Other studies conducted in the seacoast watershed also provide important information on bacterial sources, land use impacts and stormwater-borne microorganisms:

- Land Use Impacts on Nonpoint Source Pollution in Coastal New Hampshire Watersheds (1994)
- Monitoring of Dry Weather Bacteria Levels in Stormwater Detention Systems (1998)
- Public Health Significance of Stormwater-Borne Microorganisms (1999)
- Stormwater Contamination of New Hampshire Tidal Rivers (1999)

Seabrook undertook two studies to assist in the development of management plans, including the 2000 Town of Seabrook Master Plan and the 2003 NPDES Phase II Stormwater Management Plan. In addition, a citizen survey was completed in 1998 to gauge the public's concern over the most critical issues to address; these were identified as being sprawling growth, water quality impairments and the appearance of the Route 1 corridor (Cains Brook Management Plan 2006).

Simply monitoring for the presence of potentially pathogenic bacteria is sufficient to inform management decisions about whether to close a beach or shellfish bed. However, it is *insufficient* as a means to understand the possible sources and causes of bacterial pollution (Noble *et al.* 2003). To do that, more advanced testing is needed. Microbial Source Tracking (MST) is one method that can be used to match molecular, biochemical and/or chemical signatures of bacteria isolated in a water body to various hosts (Santo Domingo *et al.* 2005). While there is currently no standard method for performing MST studies (Meays *et al.* 2004), it is a growing area of research and technology development, and has been applied in numerous watershed-scale studies. The process can involve cataloguing individual strains of bacteria by either phenotypic or genotypic traits into a library that can be used in source species matching, similar to a human fingerprint database.

Ribotyping of *E. coli* is one particular method of MST fingerprinting to assess the origins of bacteria "whereby highly conserved [ribosomal ribonucleic acid (rRNA)] genes are identified using oligonucleotide probes after treatment of genomic DNA with restriction endonucleases" (Scott *et al.* 2002). It is an effective method to differentiate multiple source species due to the fact that *E. coli* strains are adapted to specific host gastrointestinal environments (Meays *et al.* 2004). Ribotyping is a highly reproducible technique that can be expensive and labor intensive, but for which there is no standard methodology (Meays *et al.* 2004). A relatively high degree of certainty (known as the similarity index) must be utilized to ensure that sample and library matches are truly indicative of a source species.

The University of New Hampshire (UNH) Jackson Estuarine Labs (JEL) conducted the Tracking Bacterial Pollution Sources in Cains Brook/Mill Creek Watershed (Jones, Landry & Edwards 2005) study as a collaboration with NH DES and the Seabrook Conservation Commission (SCC). The study revealed that wild animals contributed the largest amount of fecal bacteria (28%), followed by livestock (19%), chickens (17%), humans (15%), pets (12%), and birds (9%) (Jones, Landry & Edwards 2005). While these source-by-species data are valuable, they are insufficient in and of themselves to determine the causes of bacterial pollution. In order to do that, multiple data sources must be compared, including GIS data, land use assessment data, and even anecdotal evidence from Seabrook residents and business people.

The dredging of Cains Pond was the impetus for developing the Cains Brook/Mill Creek Watershed Management Plan (hereafter: the Cains Brook Management Plan) because when funding to improve a watershed's resources is provided through Clean Water Act 319(a) grants, the need for the dredge had to be adequately documented (3 pers. comm. 5/26/09). NH DES, which administers these grants, provided about $68,000, according to Governor and Executive Council Minutes (June 13, 2007) to develop the Plan, which has been used as the principle document that has guided the restoration. It includes an Action Plan that lays out specific management activities that ought to be undertaken. The Cains Brook Management Plan was finalized in 2007, utilizing the results of the studies mentioned above as well as conducting new ones, and is available online at www.nhep.unh.edu/resources/pdf/cains_brook_and-tos-06.pdf through the NHEP. An update to the Plan is currently in the works as of June 2009, and it will be incorporated into the next revision of the Town of Seabrook Master Plan (3 pers. comm. 2/11/09). While the Plan does focus on bacterial pollution reduction, it also addresses other needed land and resource use changes; however, this study focuses on the former.

I. Study Framework

This study was guided by the policy sciences analytical framework as first developed by Harold Lasswell in the 1950's and later expanded upon in various natural resource management literature (*e.g.* Clark 2002). It can be used to understand, analyze and improve policy across disciplines, and it examines decision making from both the human perspective and resultant environmental effects (Clark, Willard & Cromley 2000). It is a systematic and verifiable technique to go about answering complex environment-related dilemmas because it employs a widely applicable, human-ecosystem-based approach, as opposed to examining non-human ecology and/or biology alone (Clark 2002). At its core, it is a method that employs a dualistic approach to problem solving because it focuses on both the comprehensive world view as well as the immediate parochial one.

To effectively manage natural resources, it is important to consider that human behavior is the first thing that must be understood, and altered should the need arise. The policy sciences analytical framework examines four aspects of the policy process – problem orientation, the social process, the decision process and the observational perspective of the researcher. Problem orientation "mapping" is the process whereby problems are accurately specified and solutions are envisioned. This chapter provided an orientation to the problem of bacterial pollution in the Cains Brook watershed. The social process of any issue can be mapped to understand the contexts and situations in which all of the relevant players have a role. Similarly, the decision process can be mapped to understand how policy development and implementation take place as well as the resultant policy effects. The instruments used in this study aimed to gather information on both the social and decision processes of the Cains Brook watershed restoration. Lastly, a critical step in this process involves reducing biases and value judgments by stating and clarifying one's observational standpoint. These aspects of the framework have guided the development of the methodology for this study, as explained in Chapter III, as well as defined the reporting structures for the chapters that follow.

CHAPTER III.

RESEARCH APPROACH

The purpose of this research was to determine the extent to which the Cains Brook watershed restoration is being implemented using present and subsequent policies and land management practices to successfully ameliorate the problem of bacterial pollution. This chapter will highlight the research objectives and questions used to frame the study, as well as describe the methods used to obtain and analyze its data to complete the policy implementation audit.

A. Research Objectives

Table 3.1 lists the specific research objectives that were used to formulate this study's questions and determine appropriate data collection methods and reporting structures. Each study objective was fulfilled using a systematic analysis, based on the policy sciences analytical framework, of relevant literature and scientific reports, focused interviews and an online survey questionnaire. Multiple data collection methods were employed in order to corroborate the validity and applicability of collected data. Excluding several components of the survey questionnaire, the research methods used in this study are qualitative.

Table 3.1. Research Objectives.

1.	To identify how the Cains Brook Management Plan incorporates data on the sources and causes of significant bacterial pollution and intends to employ appropriate management techniques in restoration efforts;
2.	To assess the degree of knowledge about the problem of bacterial pollution and methods of bacterial pollution mitigation among the parties involved;
3.	To examine the degree to which appropriate parties have been involved in the Cains Brook restoration and policy process; and,
4.	To assess the appropriateness and effectiveness of current and future management initiatives and activities based on MST data and BMPs.

B. Research Questions

Table 3.2 specifies the research questions that were used to frame the study.

Table 3.2. Research Questions.

1.	What are the known sources and causes of bacterial pollution in the Cains Brook watershed?
2.	To what extent are local officials, business owners and Seabrook citizens aware of the problem of bacterial pollution in the watershed?
3.	To what extent are local officials, business owners and Seabrook citizens aware of established BMPs and other mitigation efforts to minimize bacterial pollution?
4.	What are the criteria used to identify appropriate restoration efforts based on land use types and identified bacterial sources?
5.	To what extent are MST data used to accurately identify bacteria sources and causes?
6.	In what ways, if any, are current Cains Brook restoration efforts following prescribed BMPs to minimize bacterial pollution, and how are these monitored and enforced?
7.	What are the projected trends in bacterial pollution of the Cains Brook watershed and how will follow-up measures be employed?

What follows is a discussion of the methods used to gather, interpret and report upon the results of this study.

C. Research Methods

An analysis using the policy sciences analytical framework requires the investigator to be clear, forthright and realistic about his or her perspectives (Clark, Willard & Cromley 2000). Being upfront about how one fits into the policy process, whether as a passive observer or active participant, is a critical step to elicit and reduce biases. I sought to assist the Cains Brook watershed restoration process by examining the efficacy of its efforts to limit bacterial pollution. Therefore, I generated this report, summarizing policy decisions that have affected and will continue to affect the progress in reducing bacteria, suggesting new alternative management practices that might be used as well as evaluating current practices and bacterial pollution causes and sources.

The research process involved working closely with several members of the Cains Brook watershed restoration. Our interactions occurred in person, over the phone, and via email. During these periods of contact, I informed my study participants of my own personal observational perspectives by explaining my interests in assisting the restoration and describing to them, in brief, my educational and professional backgrounds, as well as the overall research approach using the policy sciences analytical framework.

From my perspective, there are a variety of reasons to preserve waterbodies within urbanized watersheds. Cains Brook and its associated ponds, for example, have strong historical, cultural, aesthetic and ecological values that help to define the character of Seabrook. As land use changes around the Brook have increasingly diminished its natural character and ecosystem services, its very existence has become threatened. My studies have focused on using ecosystem-based approaches to natural resource management. This approach involves the integration of scientific information about ecosystems with the dynamic human sociopolitical world in an effort to promote long-term ecosystem health (Grumbine 1994). This study scrutinized one of many potential threats to human health (*i.e.* fecal bacterial pollution) using an ecosystem-based approach, because it examined the threat at the scale of an entire watershed, accounting for the complexity and dynamism of natural and human systems.

This study employed a systematic analysis of the specific causes and sources of bacterial pollution, as well as the ways in which that pollution is managed, through a policy implementation audit. Essentially, the audit examined the decisions made (*i.e.* the implementation of the policy) that resulted in some impact to the human and physical environments (or in some cases, had no impact). The audit incorporated the findings of other studies previously conducted in and around Cains Brook, as well as other relevant literature and scientific reports. This methodology did not involve testing a hypothesis, but rather was designed to support an inquiry-based investigation and thus mined multiple sources of data in order to understand the policy process in place in that location. Some of the most critical data gathered were from primary sources, including focused interviews, survey questionnaires, and personal communication with involved parties. Other data that were collected and analyzed included MST studies, VRAP water quality assessments, watershed assessments made by environmental engineers, and also policy information from Federal Acts (the Clean Water Act (P.L. 92-500) in particular), New Hampshire Revised Statutes Annotated (NH RSA) and Town of Seabrook ordinances. These data were analyzed for similarities, as explained in Section E of this chapter, to effectively corroborate the internal and external validity of the data, as well as their reliability and applicability. This kind of "data triangulation" is an effective means to understand the differences between people's interpretations, which can be subject to personal biases, and other data. Construct validity can be maximized using this technique because the multiple sources of evidence serve to provide more than one measurement of the same phenomena (Yin 1994). Jick explains that more than one data source should be used to effectively ensure that variations in the data are explained not by the method, but by the phenomenon itself: "It is largely a vehicle for cross validation when two or more distinct methods are found to be congruent and yield comparable data" (Jick 1979; 602). Multiple confirmations of a phenomenon, and conversely, divergences, present a valuable discovery in this type of investigation. Data triangulation is also an effective means of learning more about the social processes that occur during any natural resources management activity because it gives insight into the backgrounds of people and the situations in which they interact (Taylor & Bogdan 1998).

1. Objective 1

The first objective of this study was to identify how the Cains Brook Management Plan incorporated data on the sources and causes of significant bacterial pollution and intended to employ appropriate management techniques in restoration efforts. Accomplishing this objective involved determining how the principal guiding document being used to guide the Cains Brook watershed restoration has incorporated data on bacterial pollution sources and intends to limit those sources based specifically upon identified BMPs. This process involved examining the Cains Brook Management Plan (2006), focusing on the Watershed Action Plan and Implementation Plan as outlined on pages 46-58 and 59-63 of the Plan, respectively. The results of this analysis were incorporated into a policy implementation audit matrix (Table 4.1) that describes BMPs, the policy (or policies) that permit for and/or require BMP enactment, the status of BMP implementation (if any) with associated dates, the party (or parties) responsible for implementation and enforcement, and possible or actual risks/benefits of implementing BMPs or not implementing them.

2. Objectives 2 and 3

The second objective of this study was to assess the degree of knowledge about the problem of bacterial pollution and methods of bacterial pollution mitigation among the parties involved, while the third objective was to examine the degree to which appropriate parties have been involved in the Cains Brook restoration and policy process. Both objectives two and three were accomplished using similar methods in an effort to deduce the breadth of knowledge about the problem of bacterial pollution and associated control methods and to understand the extent to which the appropriate parties have played a role in the restoration, respectively. These objectives were achieved using a systematic analysis, described below, of focused interviews and an online survey questionnaire (incorporated into Table 4.1), largely as discussion of the *status* of BMP implementation.

3. Objective 4

The fourth and final objective of this study was to assess the appropriateness and effectiveness of current and future management initiatives and activities based on bacterial source tracking data and BMPs. Objective four examined the current and planned management initiatives and activities that are and will be employed to limit bacterial pollution in the Cains Brook watershed based on prescribed BMPs and the recommendations of other studies. The results of the baseline data used to accomplish this objective are based upon the responses to question 12 – 18 in the focused interview questionnaire and questions 11 – 18 of the survey questionnaire. The results of this analysis are incorporated into the matrix in Table 4.1. The matrix was divided into subject headings based on the similarity of intended BMP outcomes. These categories include: stormwater management techniques, pet waste and manure management, bacterial source identification and monitoring, WWTF and septic sewer management, litter/trash prevention, pond management and miscellaneous.

D. Study Instruments

Initially, a literature review was conducted to gather information about the sources and causes of bacterial pollution in small, urbanized watersheds. This literature was found in both peer reviewed material and scientific reports. Afterwards, a review of Federal, State and local policies was completed to understand how bacterial inputs are managed, monitored and enforced. This information was gathered primarily from the NH RSA online database (available at: http://www.gencourt.state.nh.us/rsa/html/indexes) and also from the Cains Brook Management Plan (2006) and other technical reports.

Once this information was gathered and compiled, a focused interview questionnaire (Appendix I) was developed, adhering to the policy process analytical framework as outlined in Clark (2002). The interview questionnaire is divided into three parts to capture the broad scope of the restoration: problem orientation, social process and decision process. Questions about the problem of bacterial pollution were asked to clarify the goals of stakeholders, to understand trends, to understand the factors that have influenced these trends, to project future trends and to elicit potential solutions (Clark, Willard & Cromley 2000). Questions about the social process sought to understand the perspectives of participants involved in the restoration, the situations in which they interact, and resultant outcomes. The decision process was targeted to understand the broader context in which decisions have been made about how to determine and manage fecal bacterial sources and causes.

Once completed, the focused interview questionnaire was submitted to the UNH Institutional Review Board (IRB) for review in order to comply with rules that govern the use of human subjects in research. A letter of informed consent (Appendix II) was also prepared as a means to inform study participants of the nature of the research, to permit recording of the interviews, and to be allowed to quote interview responses. Approval to conduct interviews was granted by the IRB on October 23, 2007 (Appendix III).

The Cains Brook watershed restoration has been guided by several organizations and individuals, including Seabrook officials, State entities, and environmental engineers, utilizing the Cains Brook Management Plan (2006) as their “blue print” for action. For the purposes of this study, only key informants were selected to provide primary data through focused interviews, which were conducted between November and December of 2007. “Key informants” were first determined using the Cains Brook Management Plan (2006). The Chief Engineer of Waterfront Engineers, Inc. was selected to be the first interviewee because of his responsibility as lead consultant for the development of the Management Plan, an undertaking that made him familiar with the state of Seabrook’s water resources, the ongoing activities and future plans to conserve those resources, and the people involved in the restoration. The second participant was selected to provide insight into the process behind and outcomes of MST studies because of his role as a principal investigator in those studies. The Chair of the SCC was interviewed third in order to provide perspective as a Seabrook town official and also for having a long history as a Seabrook resident. During these first interviews, all three participants suggested other individuals/organizations that had had an important role in the restoration. This form of targeted (or "snowball") sampling allows a researcher to gather information until it is saturated, *i.e.* no new information or viewpoints are expressed, although this method can result in small groups of interest being overlooked since participants usually nominate only well-known individuals sympathetic to their views (Routio 2007). Appendix IV provides a list of the individuals interviewed, the general role(s) that they played in the restoration (according to their own interpretations) and date the interview occurred. It is important to note that the roles of several individuals involved in the restoration have changed during the time that this study was conducted.

Notes were taken during the interviews to supplement the audio recordings. All of the participants agreed to allow the interviews to be recorded and their statements quoted. Participants were informed that their identities would be protected by using the titles of their profession. Throughout this study, interviewees and survey participants are referred to by unique identifiers, as shown in Appendix IV.

No interviews occurred during 2008, and, therefore, a second, semi-structured interview was conducted with the Chair of the SCC on February 11, 2009 in order to gather updates on restoration activities that had taken place since the previous interview. In addition, one interview was conducted with a UNH research professor on March 6, 2009, to gain the perspective of an expert who is not involved in the restoration, but is aware of the restoration because he has conducted scientific studies in Seabrook in recent years. These interviews, too, were recorded with written consent of the interviewees.

To resolve remaining information gaps, an online survey questionnaire (Appendix V) was created using Survey Monkey© (http://www.surveymonkey.com) and administered to three individuals that had not previously been interviewed. The survey, which was based closely on the focused interview questionnaire, was submitted to the UNH IRB for approval, which was granted on 4/10/09. Survey participants were selected based on the recommendations of other participants. Surveys of these individuals were used in place of interviews because other participants indicated that these individuals had not been as intimately involved in restoration activities or had since changed occupations or moved away. Online surveys were conducted in April and May of 2009 (see Appendix IV for a list of participants). Participants were provided with an informed consent document similar to the one provided to interviewees. All of the survey participants agreed to allow their statements to be quoted.

A total of eight interviews and three online questionnaires were conducted. Of note, there were several requests for interviews and surveys that went unanswered. No officials or residents of Salisbury, MA were interviewed or surveyed, although one written letter was sent to three individuals and followed up with email requests for an interview. In addition, two requests to complete the online survey were supplied to the Manager of the Seabrook Department of Public Works (DPW) and the Program Manager of the NH DES Shellfish Program, although responses to these surveys were never received. The lack of input from these individuals may yield data gaps this research.

In some instances, the interviews and surveys provided information that does not directly relate to bacterial pollution *per se*, but may be useful nevertheless to better understand the context in which decisions are made about the direction of the Cains Brook restoration. When it was deemed necessary, follow-up questions to interview and survey responses were posed to participants in person and via email. The responses to these follow-up questions were included, where appropriate, in the analysis of the interviews and survey questionnaires.

Lastly, a site tour guided by the Chair of the SCC was conducted on May 4, 2009 to help characterize the status of the Cains Brook watershed and ground-truth information gathered during interviews and surveys. The site tour revealed management applications to limit bacterial pollution, including those that are currently in place as well as those that are planned. Photos were taken using a 10 megapixel Nikon digital camera. Notes were also taken. The site tour began at the junction of Mill Creek and Causeway St. and proceeded upstream, ending at the culvert under the eastern side of I-95. A portion of the Salisbury, MA section of the watershed that includes Folly Mill Brook, which is a small tributary to Cains Brook, was also visited.

E. Focused Interview and Survey Questionnaire Analysis

Interviews were transcribed using MacSpeech Dictate© speech-to-text software. They were then twice reviewed for accuracy and the transcriptions were updated as needed. Once complete, the responses from interviews and online survey questionnaires were analyzed line-by-line, and incorporated into a coding scheme based closely on the seven research questions listed in Table 3.1:

A. Sources of fecal bacteria;
B. Causes of bacterial pollution;
C. Awareness of the problem of bacterial pollution;
D. Awareness of BMPs;
E. Criteria used to identify and select BMPs;
F. Extent to which MST data are used; and,
G. Extent and effects of BMP application now and in the future.

This coding scheme was developed based on the policy sciences analytical framework, such that an orientation to the problem of bacterial pollution was targeted through the above headings A and B, social interactions were targeted through headings C and D, and decision functions were targeted through headings E through G. Some interview/survey passages were relevant to more than one of the above headings and were, therefore, included more than once as needed. Once each interview and survey had been broken down according to this scheme, responses were examined for content similarities and differences, as well as to data from other literature. This qualitative analysis provided a method to ascertain information about the state of affairs of fecal bacterial pollution and related management efforts in the Cains Brook watershed. It also shed light on likely future trends in fecal bacterial contamination and management.

CHAPTER IV.

RESULTS

This chapter summarizes and presents data collected and analyzed from the policy implementation audit, literature review, focused interviews, and online surveys.

A. The Policy Implementation Audit

Table 4.1 presents the results of the policy implementation audit, which examined the specific management activities that have been pursued as a part of the Cains Brook watershed restoration, focusing specifically on those activities intended to reduce fecal bacterial pollution in surface waters. It also lists the relevant policies that have guided management decisions and actions, as well as the status of implementation of the various activities, the parties responsible for both implementation and enforcement, a list of unique risks or benefits associated with each BMP and information sources.

Table 4.1. Policy Implementation Audit: BMP Matrix

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Stormwater Management Techniques						
Outreach and Education 1. Provide/Distribute information on stormwater management techniques to residents and local businesses 2. Request volunteers to participate in creating catch basin signage, litter cleanups and stream cleanups 3. Provide stormwater management info on local access TV	NPDES Phase II	**1.** The DPW has posted information on the Town website: - Full-size poster for community events - 1-page brochure for distribution - 1-page fact sheet for downloads These documents discuss, in brief, the definition and impacts of stormwater runoff, as well as solutions to reduce polluted stormwater runoff for homes and businesses. They are available at the Town Hall, Community Building and Library. Seabrook distributed brochures to 385 businesses with on-site stormwater infrastructure in 2009; Distributed 400 doorknob hangers to residents in 2008. **2.** SCC and DPW have requested volunteer assistance at local schools, community events and on local access TV. **3.** Video shown at local schools and run on Town Hall TV.	- SCC - DPW - Earth Tech Inc.	N/A	Benefit: easy access to information via website Risk: internet may not be accessed by all audiences; locations for brochure are limited	-Seabrook Website -EPA 2008 -3 pers. comm.. 2/11/09
Encourage public reporting of illicit connections/discharges Distribute information to inform public on best methods to report illicit connections/ discharges and provide hotline for immediate reporting	NPDES Phase II	Currently in development phase.	-DPW -Seacoast Stormwater Coalition	N/A	Benefit: encourages public participation and may ultimately allow for wider-scale reporting	EPA 2008
Shoreline protection using vegetated buffers Shoreline vegetation must be protected where it provides shade and erosion control through such mechanisms as conservation easements and land purchase. Native planting must occur and must be maintained. Vegetated buffers act as a filter for stormwater pollutants, causing sediment and floatables to fall out of suspension.	- NH RSA 483-B - NPDES Phase II - Clean Water Act	The average size of vegetated riparian zones along both banks of Cains Brook are no more than 20 ft. This buffer width is below the mandated 50 ft stipulated by NH RSA 483-B, and far below the recommended 100 ft, according to some organizations. The first action item listed in the Cains Brook Management Plan Watershed Action Plan seeks to protect shorelines.	-SCC -DPW - Rockingham County Land Trust -Property Owners -Developers -NH DOT	NH RSA Commissioner, with advice/ assistance from various agencies	Benefit: Buffer installation can be accomplished at a minimal cost to the Town (especially if completed by residents and businesses) and require minimal maintenance.	-Cains Brook Management Plan 2006, 59 -VRAP 2009 - Chase, Deming & Latawiec 1995

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Construction operation guidelines Seabrook Stormwater Rules and Regulations require construction practices to include measures to control sediment input and erosion through use of vegetative buffers, drainage ways, site coverage, and other run-off control methods; also required are the development of construction site spill plans, a waste disposal plan, and stormwater pollution prevention plans.	- Seabrook Stormwater Rules and Regulations - NH RSA 485-A:13 - NPDES Phase II - Clean Water Act - Title X Public Health Chapter 149-M Solid Waste Management	Guidelines completed. Guidelines implemented during construction, although compliance enforcement is difficult.	- Seabrook Planning Board - DPW - Developers	Code Enforcement Officer		EPA 2008
Inspection of new stormwater infrastructure systems Before installation of stormwater management systems, design specifications must be inspected by the SB DPW and Planning Board. If the impervious surface area will exceed 20 percent, a stormwater management system shall be implemented and maintained which is designed to infiltrate increased stormwater from development occurring after the effective date of this paragraph in accordance with rules established by the department under NH RSA 485-A:17.	- NH RSA 485-A:13 - NPDES Phase II - Clean Water Act - Title X Public Health Chapter 149-M Solid Waste Management	Seabrook conducts inspections of construction sites and has a procedure for reporting non-compliance. The DPW Manager conducted 15 inspections during construction projects. There is also a Municipal Stormwater Drainage System of Rules that regulate operation and maintenance of stormwater infrastructure.	- DPW - Seabrook Planning Board	DPW, Code Enforcement Officer		EPA 2008
Mapping, posting and monitoring of stormwater outfalls The ends of pipes discharging stormwater into receiving waters are marked These must be monitored for discharges and structural soundness.	NPDES Phase II	All known outfalls were mapped and posted before 2008. 27 outfalls were re-inspected in 2008.	- DPW - Earth Tech, Inc.	N/A	Risks: Stenciling patterns do not last long Benefits: Steel markers are essentially permanent	-1 pers. comm. 5/2/09 -EPA 2008
Mapping, monitoring and cleaning of manholes Manholes are mapped, monitored and cleaned of floatable trash and sediment.	NPDES Phase II	As of 2008, an estimated 98% of the Seabrook stormwater system is mapped.	- Earth Tech, Inc.	Code Enforcement Officer		EPA 2008

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Mapping, monitoring and cleaning of catch basins Catch basins are mapped, monitored and cleaned.	NPDES Phase II	As of 2008, an estimated 98% of the Seabrook stormwater system is mapped. NH DES provided $9,000 to Seabrook to install metallic "No Dumping" discs. Discs installed in 2008.	- Earth Tech, Inc.	Code Enforcement Officer	Risks: Stenciling patterns do not last long Benefits: Steel markers are essentially permanent	-3 pers. comm. 12/13/07 -EPA 2008
Mapping and monitoring detention/retention basins Detention/retention basins are essentially artificial lakes used to detain contaminated stormwater runoff to allow settling and, to some degree, filtration, of pollutants. They are used for water quality improvements, groundwater recharge, flood protection and aesthetic improvements as well. They reduce the negative impact of stormwater flow of surface waters.	NPDES Phase II	As of 2008, 98 detention/retention ponds have been mapped throughout Seabrook	- Earth Tech, Inc.	N/A		EPA 2008
Develop rules and regulations for enforcement of illicit connections and discharges A systematic method is needed to enforce regulations to prevent new or continued illicit connections to storm and municipal sewers and eliminate discharges.	NPDES Phase II	Completed	Seabrook Planning Board	Local authorities		EPA 2008
Determine IDDE areas and monitor Certain areas and structures are likely to contribute untreated effluent and/or wastewater. These areas must be identified and the sources, eliminated.	NPDES Phase II	Before 2008, all known outfalls mapped and no evidence of illicit connections/discharges discovered	Earth Tech, Inc.	Inspection Agents, Local authorities		EPA 2008
Detect non-stormwater discharges Contaminated discharges can occur during dry periods either through intentional releases or malfunctioning systems.	NPDES Phase II	DPW informed businesses that inspections would begin in 2008	- Earth Tech, Inc. - Seacoast Stormwater Coalition	Seacoast Stormwater Coalition		EPA 2008
Remove illicit connections and discharges and evaluate post-removal	NPDES Phase II	DPW will continue to inspect commercial areas for illicit connections/ discharges	-DPW -Seacoast Stormwater Coalition	- DPW - Code Enforcement Officer		EPA 2008

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Encourage public reporting of illicit connections/discharges Distribute information to inform public on best methods to report illicit connections/discharges and provide hotline for immediate reporting	NPDES Phase II	Currently in development	- DPW - Seacoast Stormwater Coalition	N/A	Benefit: encourages public participation and may ultimately allow for wider-scale reporting	EPA 2008
Use of sand filters Slow sand filters use biological processes to remove pollutants at a constant rate. Stormwater is essentially percolated through sand that has an associated biofilm, which kills bacteria.	No mandated use but fits under NPDES Phase II	No discussion of implementation at this time	Likely: - SCC - DPW	N/A	Risk: Filters must operate only occasionally because of the potential for overloading; filter must be made as small as possible for cost effectiveness; filters must not contribute to increased flooding; Biofilms are hard to control and have the potential to become dominated by pathogenic bacteria Benefit: May require only occasional cleaning (minimal maintenance)	-Urbonas n.d. -7 pers. comm. 3/6/09
Use of sphagnum moss and juniper fiber filters Sphagnum moss (and juniper fibers) can be used as a medium for biological filtration. As filters, they have approximately 7,000 times more surface area than sand filters, making them an excellent candidate for biofilm production.	No mandated use but fits under NPDES Phase II	Some discussion by engineer consultant. Further exploration recommended.	Likely: - SCC - DPW	N/A	Risk: Uncertain tolerances of chlorides and heavy stormwater flow; Accumulation of suspended solids can limit filtering capacity; Biofilms are hard to control and have the potential to become dominated by pathogenic bacteria Benefit: Minimal maintenance	-1 pers. comm. 5/22/09 -Byrd *et al.* 2001 -7 pers. comm. 3/6/09
Install stormwater treatment device in Cains Pond The device will control sediment and trash input into Cains Pond. Both sources of pollution are common along Route 1.	No mandated use but fits under NPDES Phase II	Seabrook received a Clean Water Act 319(a) watershed assistance grant from NH DES to install a stormwater treatment catchment structure near Route 1. Installation is planned for the summer of 2009. Funds will be supplemented by Lowe's as a part of larger scale Cains Pond restoration. The dredging process was delayed because Cains Pond had to be officially listed as an impaired water under NH DES.	- NH DES - DPW	N/A	Risk: Roadside stormwater treatment devices can result in increased water temperatures that encourage bacterial biofilm growth; will require monitoring and occasional cleaning. Benefit: Long-term, minimal maintenance solution.	-3 pers. comm. 12/13/07 -5 pers. comm. 12/20/07 -7 pers. comm. 3/6/09

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Pet Waste & Manure Management						
Outreach campaign for pet waste Outreach to local residents should encourage people to limit free roaming of pets and livestock, particularly close to surface waters and catch basins, as well as provide materials to inform residents about proper waste disposal techniques.	NPDES Phase II	A pet waste pickup brochure was created and sent out in 2008. a report on the success of the outreach has also been filed with NH DES. The Seabrook pet waste program is based on the larger scale Dover, NH pet waste program. The brochure is listed on the Seabrook Town website	- SCC - NH DES	N/A		- 3 pers. comm. 5/7/09 - 5 pers. comm. 12/20/07 - www.seabrook nh.org
Licensure of pets Every 2 years, re-licensing of pets is required.	Seabrook Ordinance	Re-licensing occurs every two years. A mailing is sent to all currently licensed pet owners to remind them to complete re-licensing, and the Pet Poop brochure was included in this mailing.	Pet Owners	Town of Seabrook		1 pers. comm. 11/30/07
Clean up after and dispose of wastes properly Seabrook ordinances require the immediate removal of pet wastes from public and private property, unless the waste is on the owner's property. This "Pooper Scooper" ordinance is often associated with a fine in the case of noncompliance.	-Seabrook Ordinance Section 152-13 Animal Waste; Salisbury also has a local ordinance requiring removal of pet wastes NPDES Phase II	No data	Pet Owners	Code Enforcement Officer; Local Authorities	Risk: ordinance may need to require removal of pet wastes within a certain time frame to reduce suspension in runoff; May prove hard to enforce; surveys show that pet owners are unwilling to pick up pet waste even under the threat of fines.	Jones, Landry & Edwards 2005
Store-bought manure storage and use Manure is often stored in outdoor yards by commercial retailers. It should be stored in locations where it will into be subject to infiltration by rainfall which can result in contaminated runoff. Manure should be spread away from surface waters and on gentle slopes and should not be spread before rainfall.	None	The SCC has mandated improved storage of manure at commercial retailers.	SCC	N/A		Jones, Landry & Edwards 2005
Creation of Dog Parks Specially designated dog parks where pets are allowed off-leash can help to limit the aerial extent of pollution, especially if accompanied by other structural BMPs.	None	No discussion of implementation at this time.	Likely: - SCC - DPW	N/A		http://www.stormwatercenter.net/Pollution_Prevention_Factsheets/AnimalWasteCollection.htm

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Bacterial Source Identification and Monitoring						
Bacteria tracking in the Harbor Dye testing may be critical to determine flow patterns in the Harbor, especially near tributaries that have elevated bacterial concentrations, as well as near NPDES permitted outfall sites, like the Salisbury and Hampton WWTFs.	None	NH DES Shellfish and Beach Programs, in cooperation with the EPA's regional laboratory, conducted a dye tracing study on May 19, 2009 on the Little River.	- NH DES Shellfish & Beach Programs - EPA	N/A	Risk: Harbor flow patterns may be subject to weather conditions and seasonal variation.	- 1 pers. comm. 5/22/09 - Haberman 2009
MST/Ribotyping MST provides specific source-species information for fecal bacteria.	None	Several studies conducted in and around Cains Brook watershed. Results are species-specific and coupled with land use assessment to provide information on sources and likely causes of contamination. Local ribotesting expertise and lab facilities have performed most, if not all, of the MST studies in and around the Cains Brook watershed and in the NH seacoast area.	- JEL - NH DES - SCC	N/A	Benefit: Ribotyping is a better tool to determine bacterial pollution sources than other water quality measurements. Ribotyping is a valuable tool in the overall effort to improve water quality. Risk: Ribotyping can be expensive on a cost-per-isolate basis, and does not directly indicate the cause of bacterial pollution; Ribotyping is highly dependent on sampling accuracy and extent of RNA libraries	- 2 pers. comm. 12/12/07 -S. Jones pers. comm. 8/9/09 -Jones & Landry 2003 -Jones, Jandry & Edwards 2005 -
VRAP Monitoring VRAP monitors several water quality parameters in Cains Brook from May to September (2007 was first year of sampling). Tests are performed monthly at 10 locations along Cains Brook.	NH RSA 487:31	Sampling sites were chosen based on previous studies by DES and JEL. Monitoring is planned for an indefinite period of time.	VRAP	N/A	Benefit: VRAP sampling is provided at no cost to Seabrook and the results of VRAP studies are readily available to managers. Risk: *E. coli* sampling does not reveal species-specific sources of pathogenic bacteria.	-3 pers. comm. 2/11/09 -www.gencourt. state.nh.us
Provide data publicly Data is provided online and by request from NH DES. An annual report of the results of sample tests is created for use by communities.	NH RSA 487:31	Annual reports are provided on the VRAP website through the NH DES "One-Data" database and through VRAP.	VRAP	N/A	Risk: The use of the One-Data site may be difficult for non-technical experts.	-3 pers. comm. 2/11/09 -www.encourt. state.nh.us -des.nh.gov/org anization/divisions/water/w mb/vrap/index.htm

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Classification of Uses of Public Waters Once classified, it is unlawful to discharge contaminants, including those containing fecal bacteria, into any state waters such that the water quality will be reduced to a standard below the classification.	- NH RSA 485-A:12 - NH RSA 485-A:8, I-III - Clean Water Act 305(b)	Cains Brook, Mill Creek and Hampton Harbor have been classified as Class B waters, making them suitable for fishing, swimming and other recreation. After adequate treatment, Class B water can be used as drinking water. The classification process is critical to ensure proper uses of waterbodies.	NH DES	NH Court System		www.gencourt. state.nh.us
Land Use Assessment Land use assessments categorize land areas based on the type of activities that occur there.	None	A land use assessment was conducted as part of the development of the Cains Book Management Plan and MST study.	- SCC - Waterfront Engineers - JEL	N/A	Risk: Periodic updates critical, especially as development increases.	- Cains Brook Management Plan 2006 - Jones, Landry & Edwards 2005
Monitor stormwater outfalls Stormwater outfall sites must be monitored for bacterial concentrations.	NPDES Phase II	Monitoring is occurring during or just after storm events at locations above and below stormwater discharge outfalls, but the extent to which this is occurring is unclear.	- SCC - DPW			-EPA 2008 -Cains Brook Management Plan 2006
WWTF and Septic Sewer Management						
Maintenance of Sanitary Sewer System • Regular inspections of the manholes and sewer pipes; • Annual inspection of the sewer pipes that cross surface waters in the watershed particularly at Causeway Street and Centennial Avenue. • Inspect storm sewers for illicit discharges	- NPDES Phase II - TITLE X Public Health Chapter 149-M Solid Waste Management	The Seabrook sewer system is almost ten years old and should be inspected and maintained as needed on a periodic basis to minimize leaks to surface water bodies. Where sewer pipes cross the Cains Brook or Mill Creek or their tributaries, more frequent inspections should be performed.	DPW	Code Enforcement Officer		-EPA 2008 -Cains Brook Management Plan 2006
Require connection to municipal sewer system Municipal sewers are usually better monitored and managed than on-site septic storage.	Seabrook Municipal Sewer System Ordinance	99% of SB is connected to the municipal sewer system.	- Town of Seabrook WWTF - DPW	Town of Seabrook WWTF and DPW	Risk: Salisbury operates a similar municipal sewer system, but does not have hookups in the Cains Brook watershed. Massachusetts Title V requires inspections of septic systems and cesspools before a home is sold. No set plans yet to extend municipal sewer system in Salisbury to Cains Brook watershed area.	-3 pers. comm. 12/13/08 -Jones, Landry & Edwards 2005 -Cains Brook Management Plan 2006

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Mapping and posting of WWTF and sewer outfalls Sewer and WWTF outfalls must be mapped and signs posted so that the public is aware of these locations and future monitoring can continue.	TITLE X Public Health Chapter 149-M Solid Waste Management	As of 2008, an estimated 98% of the Seabrook WWTF and sewer system is mapped.	DPW	Code Enforcement Officer		-1 pers. comm. 11/30/07 -EPA 2008
Monitoring and Reporting of WWTF Overflows Each of the three WWTFs (Seabrook, Hampton and Salisbury) that contribute effluent to Hampton Harbor must report overflows under NPDES requirements, and NH WWTFs must report overflows under a Memorandum of Understanding (MOU) with the NH Shellfish Program.	-NPDES Phase II -MOU with Shellfish Program	Monitoring occurs monthly at each WWTF, although there are gaps in the reported data online (www.epa-echo.gov) (See Figure 4.6a & 4.6b).	-State Agencies -US EPA -DPW	-US EPA	Risk: Insufficient monitoring and/or reporting can result in exposure to contaminated effluent.	-S. Jones pers. comm. 7/24/9 -www.epa-echo.gov
Litter/Trash Prevention						
Litter prevention and cleanup Education and Outreach Campaign Various means of educating the public can be used to reduce littering throughout the watershed. Certain members of the restoration have led efforts to reduce the amount of litter in the Cains Brook watershed. Under NH RSA Section 236:26 Refuse on Private Land, it is unlawful to put or caused to be placed on private property any litter (which includes bottles, glass, scrap metal, paper, garbage, and other noxious materials), unless it is done by the owner of the property.	- NH RSA 485-A - Title XII: Public Safety And Welfare Chapter 163-B Litter Control Law - Title XVIII Fish And Game Chapter 215-A Off Highway Recreational Vehicles And Trails - NH RSA 236:26 - NPDES Phase II	Seabrook has sought, and been awarded, Clean Water Act 319(a) funding for outreach activities. There is a semi-annual stream walk to pick up litter. Seabrook has encouraged "Adopt-a-Spot" programs to increase community responsibility for certain at risk areas. Seabrook has encouraged local businesses to clean up their parking lots and other areas. Seabrook has also solicited volunteers from locals schools and neighborhood associations. Seabrook has also utilized local access programming and the Town website to reach out to residents. Seabrook is exploring the possibility of instituting fines consistent with NH F&G guidelines that require mandatory court hearings and an approximately $1,000 fine, as opposed to the NH DOT fine, which is only $100.	- SCC - DPW - NH DES - Community Associations	All law enforcement agencies and officers and officials, and forest and park patrols	Risk: liability of allowing untrained citizens to undertake potentially risky cleanup activities due to exposure to contaminants Risk: difficulty in attracting participants	-5 pers. comm. 12/20/07 -EPA 2008 -ww.gencourt. state.nh.us

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Sweeping/cleanup of large areas of impervious surface along Route 1 Large amounts of trash (litter, windblown trash) accumulate along the Route 1 corridor. Regular sweeping can remove substantial amounts of this litter.	Seabrook Ordinance	Several business have been observed to sweep every day, although the extent to which they are reducing litter input into Cains Brook and its ponds is unknown. The DPW has implemented a program to require all curbed areas with sidewalks to be hand-swept.	Business Owners	- DPW - Code Enforcement Officer		-1 pers. comm. 11/30/07 -5 pers. comm. 12/20/07
Improve signage around catchment basins and other areas Storm drains can be stenciled or have permanent markers placed near them to discourage illegal dumping	NPDES Phase II	In 2007, Seabrook received a $9,000 grant to put signs into catch basins. Seabrook installed 750 "No dumping - Drains to Harbor" signs in 2008. 25 catch basins were also stenciled in 2008.	- DPW - SCC	N/A	Benefit: Unlike stencils, metal discs will last longer	-EPA 2008 -3 pers. comm. 2/11/09
		Pond Management				
Document Secondary Contact Recreation impairment In order to spend Clean Water Act 319(a) watershed assistance grant money, an official impairment must be listed by NH DES.	Clean Water Act Section 319(a)	The impairment was not yet officially listed as of 5/22/09.	- NH DES Wetlands Bureau - EPA	N/A		1 pers. comm. 5/22/09
Inspect shorelines for erosion Regular inspection of riparian zones for erosion, especially in highly settled areas, will help to identify the causes of erosion and reduce its impact.	None	Currently, no systematic inspection is performed, although certain areas have been identified as high risk areas, including Cains, Cains Mill and Noyes Ponds and Mill Creek.	- SCC - DPW	N/A		3 pers. comm. 5/4/09
Dredging of Secord's Pond Secord's Pond was the first major restoration activity that focused on pond maintenance. It was intended to remove potentially contaminated sediment as well as increase aquatic habitat and provide more recreational opportunities.	NPDES Phase II	The dredge was completed in the early 2000s.	- SCC - DPW	N/A	Risk: Dredging has been shown to greatly increase the presence of indicator bacteria because of sediment re-suspension	-Cains Brook Management Plan 2006 -Shillinger & Gannon 1985

BMP Title and Description	Policy	Status of Implementation	Responsible for Implementation	Responsible for Enforcement	Unique Risks/Benefits	Source
Dredging of Cains Pond Cains Pond will be dredged through about 3/4 of its footprint in order to remove potentially contaminated sediment, remove nutrients, increase aquatic habitat and fish passage and improve water quality.	NPDES Phase II	A 319(a) watershed assistance grant for $120,000 was awarded by NH DES in 2008 to dredge the pond; Lowe's provided an additional $200,000, approximately. Dredging is planned for the summer of 2009.	- NH DES Wetlands Bureau - SCC - DPW	N/A	Risk: Dredging has been shown to greatly increase the presence of indicator bacteria because of sediment re-suspension Benefit: Dredging will open up other EPA grants.	-Cains Brook Management Plan 2006 -Shillinger & Gannon 1985
Map detention/retention basins Detention/retention basins are used to manage stormwater runoff to prevent flooding downstream and to improve water quality in nearby water bodies. Mapping these basins is critical to management so that they can be monitored periodically.	NPDES Phase II	As of 2008, 98 detention/retention ponds have been mapped	- DPW - Earth Tech, Inc.	N/A		EPA 2008
			Miscellaneous			
Adoption of Cains Brook Management Plan into the Seabrook Master Plan By adopting the Cains Brook Management Plan into the Seabrook Town Master Plan, attention to watershed restoration issues will be enhanced and	Town of Seabrook Master Plan	The Cains Brook Management Pan was adopted into the Seabrook Master Plan in 2008.	- SCC - Seabrook Planning Board	N/A		3 pers. comm. 2/11/09
Updating Cains Brook Management Plan The Cains Brook Management Plan is a "living document" that requires periodic updates to more effectively describe the problems, solutions and successes/failures.	No mandated use Fits under NPDES Phase II	The 2009 update is in final draft form, but had not yet been officially accepted by NH DES as of June 2009. The new version has more maps, updated statuses of restoration activities, and MST studies were better explained.	- SCC - Waterfront Engineers	N/A	Benefit: updating the Plan to EPA standards will allow Seabrook to apply for more grants	3 pers. comm. 2/11/09
Encourage natural flow pattern of Cains Brook Creation of a more natural water retention structure at Cains Pond will ensure water levels remain at appropriate levels, as well as to permit for fish passage, maintain aquatic habitat and increase oxygenation.	None	A 319(a) watershed assistance grant has provided sufficient funding to create a natural rock pool riffle at the Route 1 culvert at Cains Pond.	- SCC - Waterfront Engineers	N/A		3 pers. comm. 2/11/09
Documenting the restoration process The SCC is documenting the progress of the watershed restoration by interviewing Seabrook residents and noting BMP successes and/or failures.	None	The documentation process is ongoing, but it is unclear as to what will become of it.	SCC	N/A	Benefit: documenting the progress of the restoration will provide a historical account of activities and also increase public awareness	3 pers. comm. 2/11/09

In the next two sections, the sources of bacteria and causes of bacterial pollution, respectively, are discussed. Sources and causes are discussed separately due to the fact that fecal bacteria originate uniquely from human and animal sources, but the reasons that contamination of surface and ground waters occur are generally the result of poor management or a lack of management.

B. Sources of Fecal Bacteria

There are a variety of sources of fecal bacterial pollution in the Cains Brook watershed. Quantitative evidence for sources comes primarily from MST data and site monitoring data gathered by VRAP and data gathered as part of the Harbor TMDL assessment (EPA 2003). Interviews and surveys provided additional qualitative information on possible and actual sources as well as their locations, and the site walk also revealed likely contamination sources. In the larger Hampton Harbor MST study conducted in 2003, identified sources included pets (4% of total), wildlife (5%), birds (7%), livestock (8%), and humans (26%) (Jones & Landry 2003). The six primary sources of fecal bacteria identified by MST in the *Cains Brook* watershed include wild animals (28% of total), livestock (19%), chickens (17%), humans (15%), pets (12%) and birds (9%) (Jones, Landry & Edwards 2005).

1. Wild Animals

According to the MST study completed in 2005, wild animals contributed the most fecal bacteria of all source species (28%) to the Cains Brook watershed (Jones, Landry & Edwards 2005). Wild animals sources originated primarily from raccoon, deer and coyote, but bacterial isolates from other mammalian species were found as well, but in smaller quantities. This finding is not surprising because much of the area around Cains Brook is wooded and there are large areas of salt marsh, providing habitat and forage opportunities (Jones, Landry & Edwards 2005).

2. Livestock

Livestock contributed 19% of the total loading of bacteria in the 2005 MST study (Jones, Landry & Edwards 2005). Because chickens presented such a significant source and are not a mammalian manure-contributing livestock species, they are discussed separately from both livestock and pets. Livestock represent an interesting anomaly because the Cains Brook watershed is highly urbanized, having little open space that is not forested for raising livestock (see Figure 1.3). Bacteria originating from horses were found in some locations of the watershed, including near Railroad Avenue, Causeway Street and Centennial Street (Jones, Landry & Edwards 2005), "but apparently those horses have now moved" (1 pers. comm. 11/30/07). There was also evidence that cattle were contributing bacteria, but this source presents a quandary in that "there are no cows in Seabrook, in [the] watershed on the east side of I-95…[and] from our walking the watershed, we were not able to find any cows anywhere" (1 pers. comm. 11/30/07). "The nearest cow is about 3 miles [west of Route 1]" (3 pers. comm. 12/13/07). Other study participants expressed similar uncertainties, stating that they "don't really know what's going on down there for cattle… [but] bacteria may be brought in compost or manure. That could be… [potentially from] Home Depot" (5 pers. comm. 12/20/07). Further investigation into this potential source was conducted, and revealed that manure is kept in outdoor storage yards at several of the businesses along Route 1, including Home Depot, Lowe's and Wal-Mart (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07). After contacting the manufacturers of the manure products, it was discovered that "...typically the manure that's sold by building supply places like Home Depot is not sterile. It has not been cooked or anything to kill the bacteria. There are live bacteria still...in those bags" (1 pers. comm. 11/30/07), which are stored in uncovered outdoor storage yards less than 100 yds from detention basins and Cains Mill Pond at Lowe's and Home Depot, respectively (Site Walk 5/4/09). Studies (*e.g.* Gagliardi & Karns 2000) confirm that live pathogenic bacteria do leach from stored manure into surface and ground waters, although the extent to which leaching has occurred from this source in Seabrook is unknown.

3. Chickens

Chickens contributed a total of 17% of the bacteria found in the watershed (Jones, Landry & Edwards 2005). As of this time, no thorough census has been taken of the total number of chickens in the Cains Brook watershed, but it is likely that there are "a lot of people [that have] chickens in their backyards... because chickens were pretty significant [in source tracking studies]" (5 pers. comm. 12/20/07). Jones, Landry & Edwards (2005) confirm that there are indeed numerous chicken hobby farms throughout the watershed. Contaminated runoff from poultry can be a major source of contamination in residential areas (Geldreich 1996), such as those east of Route 1 in Seabrook.

4. Humans

Human contributions accounted for 15% of the total bacterial loading in the Cains Brook watershed and are considered to be significant in all of its watercourses (Jones, Landry & Edwards 2005).

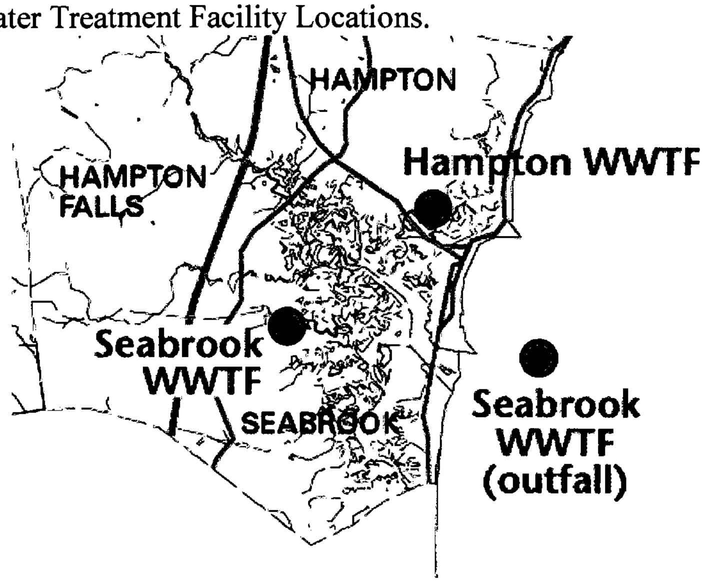
i. Wastewater and Sewage Effluent

Despite efforts to eliminate pathogens from human sewage, bacteria levels in shellfish growing areas of the Harbor "often exceed the limits set by the [NH] DES Shellfish Program, resulting in [clam] flat closures and frustrated clam diggers" (Jones & Landry 2003, 6). The Town of Seabrook is serviced almost entirely by a municipal separate storm sewer system (MS4) that was installed in 1995. Stormwater discharges from the Seabrook MS4 infrastructure contain significant numbers of fecal bacteria, especially during and immediately after rainfall (EPA 2003).

The town WWTF is located north of Cains Brook on Rural Route 286, while its outfall pipe is in the Atlantic Ocean (1 pers. comm. 11/30/07; Jones 2001) (Figure 4.1). The WWTF has been penalized in the past for exceeding NPDES permits. The EPA filed suit against the Town for Clean Water Act violations that occurred between January 1999 and August 2003, as well as a major release, whose mechanism was not discovered during this study, of some 180,000 gallons of untreated effluent on August 24, 2003, that ended up in Cains Brook (Fleming 2004).

In addition to overflows at the Seabrook WWTF, there have been "overflows during storm events from…the Town of Hampton sewage treatment plant" (1 pers. comm. 11/30/07) whose outfall pipe is situated in Tide Mill Creek, which is a tributary to Hampton Harbor (Jones 2001). In addition, Salisbury "has a sewage treatment plant down on Blackwater River that discharges into that river, so that's another potential source" (1 pers. comm. 11/30/07). The Blackwater River is a tributary to Hampton Harbor whose mouth is located just south of Mill Creek. Other NPDES permitted sites whose discharges affect the Hampton Harbor include: Morton International and KJ Quinn & Co., Inc (discharge into Cains Brook), and EnviroSystems and Aquatic Research Organisms (discharge into Taylor River). During 2008 illicit discharge sampling conducted by NH DES, one sample of *E. coli* measured >406cts/100mL for Hampton, but the source was neither detected nor eliminated (NH DES 2009). EnviroSystems and Aquatic Research Organisms both contribute a negligible amount of bacteria loading (EPA 2003).

Figure 4.1. Wastewater Treatment Facility Locations.

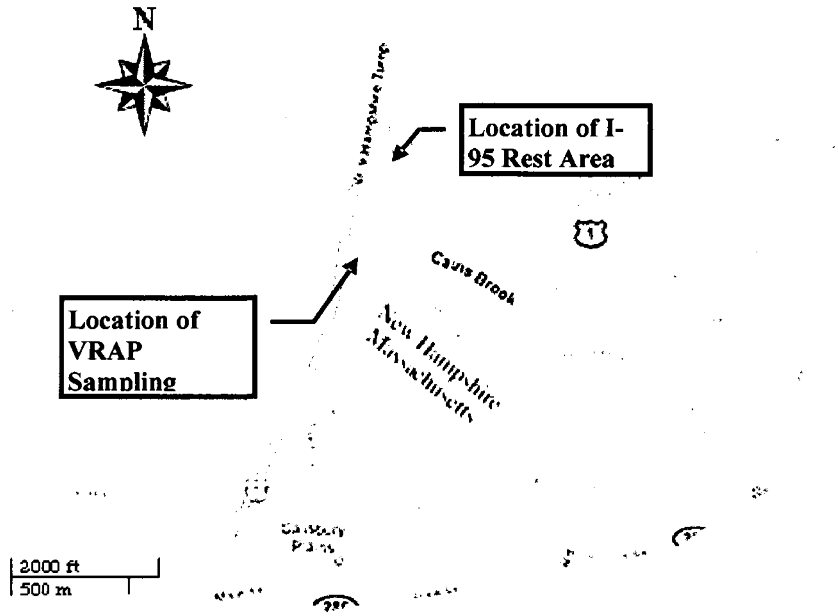


Source: Jones 2001

ii. Trash

As previously discussed, some types of trash are more likely than others to contain fecal-borne bacteria. Trash was observed in many riparian areas of Cains Brook and Mill Creek during the site walk (5/4/09). Floatable trash was also observed in the water, and some trash was on the streambed. The areas where trash was most prevalent included the Route 1 culvert between Cains Pond and Cains Mill Pond, the bridge crossing at Causeway Street, and in the forested area south of the I-95 culvert. Some of the most visible types of trash observed included food containers (half empty soda and water bottles, beer cans and bottles, fast food containers), plastic bags, cigarettes, and paper. A site inventory was completed in 2005 by several individuals who found that "some of that does appear to be coming out of the storm drain systems, [some] appears to be windblown, [and some is] being thrown out of cars" (1 pers. comm. 11/30/07). One area of particular concern is the new Rest Area built on the west side of I-95 (Figure 4.2), whose adjacent "woods are just filled with trash" (1 pers. comm. 11/30/07), although this site was not examined during the site walk. The rest area is connected to Seabrook's municipal sewer system (1 pers. comm. 11/30/07), and there is a VRAP monitoring station nearby (Station ID: 09-CNS) where bacteria and other water quality parameters are sampled (see Figure 4.7). This monitoring site consistently showed higher bacterial counts than most other stations throughout the watershed, with a geometric mean of 129 *E. coli* cts/100mL from June 27 – August 22, 2007 (the highest geometric mean recorded out of eight stations) (VRAP 2008) and a geometric mean of 340 *E. coli* cts/100mL from July 30 – September 24, 2008 (also the highest geometric mean recorded out of eight stations) (VRAP 2009). Both of these total *E. coli* counts do not meet New Hampshire Class B water quality standards. This evidence suggests that fecal bacterial contamination from the rest area *may be more significant than from any other site in the watershed*, although it is difficult to predict a cause-and-effect relationship between the presence of human-generated trash and *E. coli* counts because of other possible sources, including dogs, public toilet facilities, dumpsters and wild animals. Further study would be needed to better understand these relationships.

Figure 4.2. Location of I-95 Rest Area.

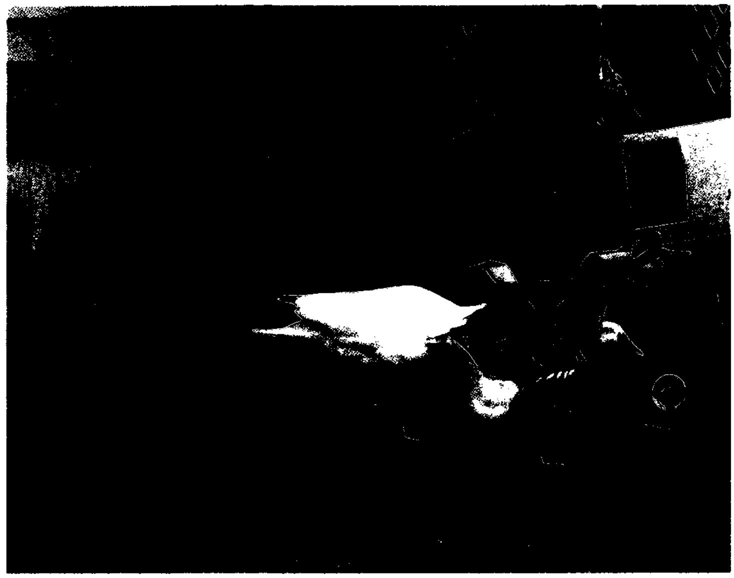


Source: 1 pers. comm. 11/30/07; Google Maps ©2009; VRAP 2009

5. Pets

Household pets contributed 12% of the total bacteria loading (Jones, Landry & Edwards 2005). Pet species included cat and dog. Fecal bacteria contributions from dogs only slightly surpassed contributions from cats (Jones, Landry & Edwards 2005). During the site walk, a pair of domesticated geese that are considered by their owners to be pets (3 pers. comm. 5/4/09) were observed in a yard adjacent to the Brook along Centennial Street, and there was a substantial amount of goose fecal matter within a few feet of the Brook (Figure 4.3). These geese have been seen in the Brook as well (3 pers. comm. 5/4/09). Geese contributed about 64% of the total avian-borne fecal bacteria, excluding chickens (Jones, Landry & Edwards 2005).

Figure 4.3. Domesticated Geese Near Cains Brook.



Source: A. Kornbluth

6. Birds

Evidence suggests that birds may play an important role as reservoirs of disease, although bird-to-human disease transference is poorly understood (Nelson *et al.* 2008). Birds (excluding chickens) contributed 9% of the total bacteria loading to Cains Brook (Jones, Landry & Edwards 2005). Specifically, bird species included goose, gull, wild turkey and sparrow. To note, domesticated geese were not distinguished from wild ones in MST studies, and are addressed here as wild birds. There has not been any further inquiry to date into the locational sources of bird fecal matter input in the Cains Brook watershed, likely because birds are so often transient "residents" and may only be present in the watershed for short periods. However, a recent study by Nelson *et al.* suggests that gulls on the Isles of Shoals, Maine, located less than 10 km east of Seabrook, obtain fecal bacteria from nearby wastewater and landfill trash, subsequently transporting them to locations where humans may recreate and/or fish (2008). This study also found that *E. coli* concentrations in gull feces were as high as 2.5×10^9 g^{-1} (Nelson *et al.* 2008). Gulls were observed in the Cains Brook watershed during this study (5/4/09). A pair of Canada geese (*Branta canadensis*) were also observed on Cains Mill Pond (Figure 4.4), and they are thought to be semi-permanent inhabitants there (3 pers. comm. 5/4/09). The geese approached the researcher closely, which, as one study participant noted, may indicate that they are accustomed to people feeding them there (3 pers. comm. 5/4/09).

Figure 4.4. Canada Geese on Cains Mill Pond.

Source: A. Kornbluth

7. Spatial and Temporal Distribution of Bacteria

While the spatial distribution of bacterial indicators has been fairly well documented along the New Hampshire seacoast (Jones 2001), discovering non-point source inputs remains a challenge. General trends show that concentrations are higher in creeks than in estuarine waters, indicating that most bacterial contributions occur upstream, but is also likely due to dilution, exposure to higher salinity (Jones 2001), and exposure to the sun in areas that have little or no canopy cover.

> "The bacteria that's closing [the] clam flats is coming out of these creeks. One of the very interesting things that we found out was, in the tidal ones, especially the two [creeks] that were most to the east, ...the bacteria content was higher [on the] incoming tide than outgoing tide. I don't know if there's been any other studies that specifically checked incoming versus outgoing [tide concentrations]" (3 pers. comm. 12/13/07).

In other studies along the New Hampshire seacoast, bacterial concentrations were higher at low tide than at high tide, typically as a function of freshwater mixing with less contaminated saltwater at high tides (Jones 2001).

Temporally, bacterial pollution in surface waters is more of a problem during autumn and winter, likely because of the higher amount of runoff associated with storm events, decreased filtration by vegetation and increased survival of bacteria in colder waters (Jones 2001). Elevated levels of *E. coli* are more common under wet weather conditions; interestingly, one New Hampshire study showed that there were no major differences in the types of source species identified during dry and wet weather conditions (Jones *et al.* 2004). In the case of stormwater control systems, evidence indicates that contamination from stormwater runoff can vary storm-to-storm and season-to-season (Jones 1998). In the Cains Brook Watershed, most, if not all, of the monitoring occurs during summer months (VRAP 2009), during which time the Hampton Harbor clam flats are closed to harvest, according to the NH F&G Clam Flat Hotline available at: http://wildlife.state.nh.us/Fishing/clam_flat_status.htm. However, the beaches are open, so summer monitoring could be used to address concerns about recreational uses.

B. Causes of Bacterial Pollution

The sources discussed previously provide helpful insight into informing management, but the reasons why they are a problem may be more difficult to pinpoint. This section discusses both identified and likely causes of fecal bacterial pollution in the Cains Brook watershed.

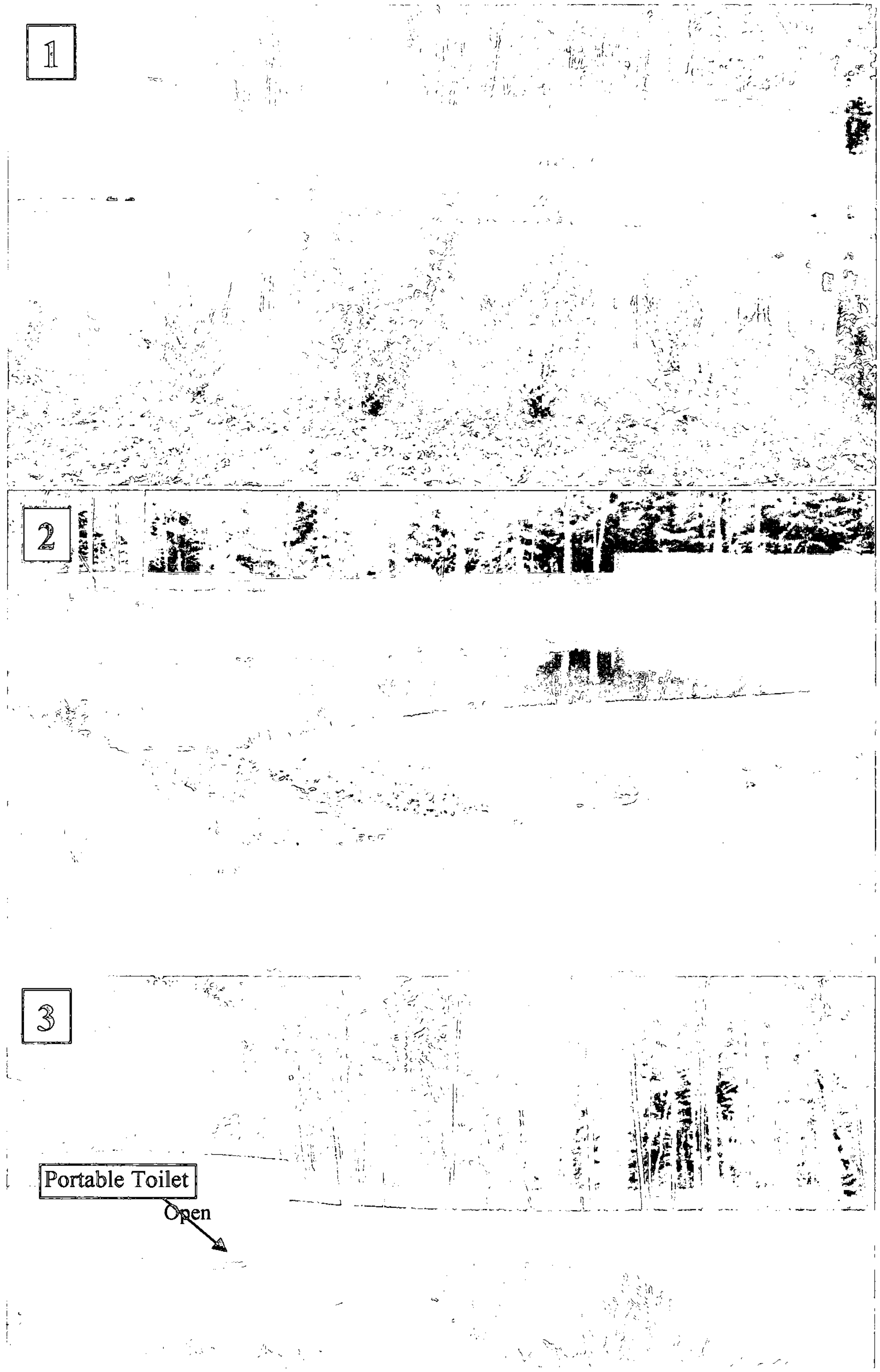
1. Stormwater Runoff and Associated Contaminants

Stormwater runoff containing fecal bacteria is a major contributor of bacterial pollution in the Cains Brook Watershed (3 pers. comm. 12/13/07; EPA 2003). In New Hampshire, stormwater runoff that results from rainfall and snowmelt is the most common cause of fecal bacterial contamination in urbanized areas, based on the presence of elevated concentrations in all monitored areas (EPA 2003; Jones 2001). In Seabrook, runoff from urbanized areas, especially those with substantial impervious surfaces including the Route 1 corridor, contribute contaminated sediment, pollutants and trash (Cains Brook Management Plan 2006, EPA 2003; Site Walk 5/4/09). Many of the storm drains in Seabrook and Hampton drain directly into the tributaries and marsh areas of Hampton Harbor (Jones 2001) and they are frequently infiltrated and sometimes blocked by trash (1 pers. comm. 11/30/07). The efficiency of Seabrook's stormwater control systems may be reduced due to the fact that "[The New Hampshire Department of Transportation] had specifically told [the designers of the system] not to put hoods on the catch basins, and not to put sumps in them because they don't have the staff or the time to maintain them" (1 pers. comm. 11/30/07). Upon further examination of several manholes, it was noticed that the system had become clogged with floatable trash (1 pers. comm. 11/30/07). That trash originates from places like the parking lots of businesses along

Route 1 and the I-95 rest stop, in particular (1 pers. comm. 11/30/07; 4 pers. comm. 12/18/07); there have been no scientific assessments of the origins of trash in the watershed. One business owner has been known to "catch [litterers] all the time... littering just outside his business" along Route 1, which is transported by wind and rain into storm sewers (4 pers. comm. 12/18/07). Three study participants expressed their concern that inadequate measures are in place to manage contaminated stormwater runoff, indicating that it is likely a problem "at times of peak stormwater discharge both from the sewer system overflows and then also from stormwater runoff in places like Home Depot" (1 pers. comm. 11/30/07). Evidence indicates that some stormwater control systems under some conditions appear to promote bacterial growth during storm events; others show that concentrations diminish or disappear during dry weather (Jones 1998).

Home Depot, Kohl's and Lowe's each have a detention basin (or pond) where stormwater runoff from their parking lots is purposefully channeled (1 pers. comm. 11/30/07; 3 pers. comm. 5/4/09; Site Walk 5/4/09) (Figure 4.5). Notice in Figure 4.5-3 the presence of a partially submerged portable toilet in the Kohl's detention pond. The Home Depot detention pond drains into Cains Mill Pond on the west side of an abandoned railway while the Kohl's and Lowe's detention ponds drain into Mary's Pond, which empty into Cains Pond west of Route 1. Studies have shown that bacterial indicators are likely to grow in wet pond stormwater control systems during periods of dry weather and are then discharged during storm events (Jones & Langan 1996). Bacterial concentrations, in the same study, were highest in wet ponds during the summer (Jones & Langan 1996), when people are most likely to engage in various water recreation activities. VRAP sampling in Mary's Brook (Station ID: 02-MRY, Figure 4.7) does not support these earlier findings, showing a geometric mean that was 38 *E. coli* cts/100mL in 2007 (VRAP 2008), and 52 *coli* cts/100mL in 2008 (VRAP 2009); both measurements meet Class B water quality standards. VRAP sampling in Cains Pond (Station ID: 04-CNS, Figure 4.7), similarly, showed that Class B water quality standards were met at that location for 2007 and 2008 (VRAP 2008; VRAP 2009). This evidence suggests that the stormwater detention basins may be providing effective treatment in terms of bacterial contaminants, although other factors are likely to play a role and further study may be valuable.

Figure 4.5. Home Depot (1), Lowe's (2) and Kohl's (3) Detention Ponds.



Source: A. Kornbluth

2. WWTF, Municipal and On-Site Sewer Inputs, and Other Inputs

While many studies have shown animal-borne fecal bacteria in stormwater runoff to be the major source of contamination, it appears that direct sewage contamination from leaky sewer pipes and illicit connections can be equally if not more of a problem in coastal New Hampshire (Jones 2001). Complicating factors include the age and design quality of sewers and WWTFs, as well as their proximity to surface waters (Jones 2001). Heavy rainfall events have occasionally resulted in overflows at WWTFs and the combination of WWTF effluent with stormwater that ends up in the Creeks (1 pers. comm. 11/30/07). However, in a municipal wastewater system that was built less than 15 years ago, overflows may be less likely (S. Jones pers. comm. 7/24/09), especially since the DPW inspects outfalls, monitors and cleans catch basins and manholes, and continues to inspect the area for illicit connections (EPA 2008; Table 4.1).

Proximity to WWTFs and their outfall pipes is a major factor that influences contamination. As stated earlier, the Hampton and Salisbury WWTFs discharge into creeks that empty into Hampton Harbor. In tests that were conducted during the construction of the Seabrook Station nuclear power plant facility, it was shown that poor flushing of the Harbor is a likely contributor to elevated bacteria counts, in that incoming tides push contaminated water into the tributaries (3 pers. comm. 12/13/07); this indication is contrary to results gathered as part of the Harbor TMDL study which indicates that about 88% of the Harbor water is flushed with *each* tide (EPA 2003).

According to study participants, the Hampton WWTF has occasionally experienced overflows during storm events, but "DES [doesn't] know about it…[and] they don't want to acknowledge it. That is part of what the Seabrook Conservation

Commission expects is a source in Mill Creek, and at some point [they] were looking at actually doing some more additional sampling locations along Mill Creek, during various stages of the tide,…tracking it across…the Harbor to see if there was an increase as you were getting closer to the Hampton sewage treatment plant" (1 pers. comm. 11/30/07).

The occurrence of several 100-year storm events, including the Mother's Day and Patriot's Day storms, exacerbates the likelihood that WWTF capacities will be overloaded (3 pers. comm. 12/13/07). While the occasional WWTF overflow does contribute elevated bacteria levels to shellfish growing areas (NHEP 2009), there was no NPDES violation reported in May of 2006 as a result of the Mother's Day storm at the Seabrook WWTF (there were no data reported for either the Hampton or Salisbury WWTFs during the same month) (Figure 4.6a; www.epa-echo.gov). There were also no reported violations at either the Seabrook or Salisbury WWTFs during April of 2007 as a result of the Patriot's Day storm (Figures 4.6a & 4.6b), and there were no data for the Hampton WWTF (www.epa-echo.gov). In addition to monitoring and reporting through the EPA, the NH DES Shellfish Program has MOU's with each New Hampshire WWTF, requiring reporting of any and all problems associated with potential releases of untreated sewage; such information is critical to protecting human health by understanding how to appropriately establish "safety zones" based on how far effluent can travel in a waterbody over a given time period.

There are also sewer mains near Cains Brook that cross under Route 1 and ultimately end up at the Seabrook WWTF (1 pers. comm. 11/30/07). On the north side of Causeway Street, there is a pumping station that would likely contaminate Mill Creek if a spill occurred there (1 pers. comm. 11/30/07). Neither of the two VRAP sampling sites along Route 1 (Station IDs: 03-CNS & 02-CNS, Figure 4.7) revealed levels of *E. coli* that exceeded Class B water quality standards in 2007 or 2008 (Figures 4.8a & 4.8b), indicating that fecal bacteria are likely not contaminating the surface waters near Route 1 to any substantial degree, at least during the summer when sampling occurs, or on/just before the dates when samples were collected.

Since a number of areas around the Harbor are still serviced by on-site septic systems (Jones 2001), including Salisbury's portion of the Cains Brook watershed (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07; Cains Brook Management Plan 2006), there is an increased likelihood that poor management or a lack of management may contribute to high levels of bacteria and nutrients into surface and ground waters. Studies suggest that fecal bacteria densities are much higher in non-sewered watersheds than in sewered ones (Young & Thackston 1999). However, during the 1995-96 study that examined the potential likelihood that septic systems in Seabrook were contributors to bacterial pollution, little evidence was found that they are, in fact, contaminating groundwater resources (Jones 2001). That study did find evidence of subsurface bacterial transport by the presence of *Clostridium perfringens* in the soil down-gradient towards marsh areas; however, *C. perfringens* is long-lived via spores, whereas *E. coli* is not long-lived in soil (S. Jones pers. comm. 8/9/09). Therefore, even though *C. perfringens* was detected, their presence could indicate contamination from a long time ago, whereas the low levels of *E. coli* in groundwaters indicated little or no recent contamination. As of July 2009, a similar study has not yet been completed in either Hampton or Salisbury. The risk of contamination due to septic system leakages and failures is increased when these systems are situated in areas that have high water tables and excessively drained, sandy soils (Jones 2001), which is the most common soil type in the upper portions of the watershed (in Seabrook as well as Salisbury) (see Figure 1.3).

In Hampton Harbor, there are documented releases of sewage from toilets on boats that can potentially affect shellfish in Hampton Harbor (NH DES 2007c). An assessment by the FDA in 2002 suggested that about 50% of the boats in the Harbor contributed raw sewage, resulting in the average release of some 238 billion organisms/day during the sampling period (EPA 2003). In contrast, there is no direct evidence suggesting that fishermen contribute to bacteria levels, although other safety hazards such as fishing lines and hooks are a threat to recreational uses of the waters both at the Seabrook Harbor, Seabrook Town, and Hampton Harbor beaches (NH DES 2009 b; NH DES 2009c; NH DES 2009d).

3. Sediment Re-suspension

Rainfall and snow melt not only contribute contaminated stormwater runoff and cause WWTFs and sewers to overload, but, along with wind, can also cause contaminated sediments to be re-suspended and transported downstream. This is particularly a problem in stormwater detention ponds, where "fine silt that used to be at the bottom of the pond and not disturbed… is now washing down[stream]" (3 pers. comm. 12/13/07). Given that there is "probably a lack of care in monitoring the development sites by state and local agencies, [there has been] a lot of sediment going into the system and a lot of nutrients going into the system and that's *still* going into the system" (7 pers. comm. 3/6/09). During a recent major storm, a dam in Salisbury located southwest of Folly Mill Road breached, "[flushing] a lot of sediment down the Brook, [including] into Secord's Pond…that was dredged by the town 3 or 4 years ago. [NH] DES is not holding Salisbury responsible for the damages, [even though] all the land below the dam is in NH [and] is being regulated by [NH] DES Dam Bureau, [which] wouldn't do anything about it either" (1 pers. comm. 11/30/07).

4. Livestock and Pet Waste

Across New Hampshire, agricultural practices have not been a major NPS contributor, but raising livestock at a small, local scale is a common tradition that may contribute bacteria to surface waters (Jones 2001; Jones, Landry & Edwards 2005). For animals kept as livestock as well as pets, there are "animals that do hang out around the water bodies and defecate…right in the water sometimes, or right next to it" (2 pers. comm. 12/12/07). Chickens, as mentioned, contributed a substantial portion of the total bacterial loading into Cains Brook (at 17%), because they are raised as hobby fowl and in small laying flocks and are housed in coops throughout the watershed (Jones, Landry & Edwards 2005, 23). When such birds are allowed to roam free or their manure is not properly disposed of, there is an increased likelihood that runoff will transport poultry wastes into nearby surface waters; these wastes have been found to contain *Clostridium, Salmonella, Bacillus* spp.*,* *Staphylococcus* spp. and *Streptococcus* spp., among other pathogens (Jones, Landry & Edwards 2005). Poor management of such inputs, or the lack of management, may be the result of an uninformed public, in the case that "somebody that just didn't read the paper or didn't see the storm drain door hangers and is doing something like [allowing wastes to enter the Brook]" (4 pers. comm. 12/19/07). There may also be a lack of appropriate enforcement capability in the town, even when gross infractions of the Seabrook "Pooper Scooper" ordinance are obvious, such as the observed goose wastes in and around the brook at Centennial Street (Figure 4.3).

5. Wild Animals and Birds

Predicting the locations and causes of fecal bacterial contamination from wild animals and birds is difficult, but it is known to be a "significant fraction of the sources that are identified [in Cains Brook]" (2 pers. comm. 12/12/07). MST studies confirm that this fraction was indeed the highest (at 28%) of all sources in the Cains Brook watershed (Jones, Landry & Edwards 2005). Of particular concern is the transfer of antibiotic resistant microorganisms to wild animals and birds, because antibiotics are shed in human fecal matter and "then can get into other organisms like seabirds. One of the things [being studied] is seagulls roosting in wastewater treatment facility lagoons and in landfills, picking up antibiotic resistant bacteria and bringing them out to the Isles of Shoals or wherever they are going" (2 pers. comm. 12/12/07; see also Nelson *et al.* 2008). According to the Chair of the SCC, human/animal interactions like feeding wild birds may serve to increase the presence of animals present along the Brook (3 pers. comm. 5/4/09). During autumn, bacterial concentrations may be increased by the presence of harbor seals and migratory waterfowl, including "literally hundreds of thousands of...shoulder-to-shoulder cormorant. [And] every single bird, before they lift off, they evacuate their bowels, they lighten the load" (3 pers. comm. 12/13/07). There is no evidence of the presence of pathogenic fecal bacteria from harbor seals in the Harbor (Jones & Landry 2003). There is, however, evidence of fecal bacteria from cormorants, which represent approximately 31% of the total number of avian species isolates found in

Hampton Harbor during a sampling season that lasted from August 2000 through October 2001; in the same study, avian sources represented only 7% of the total number of identified isolates (Jones & Landry 2003, 5). Canada geese were mentioned as a source of fecal bacteria by three participants; gulls were not mentioned as a source of bacteria, although studies have shown them to contribute highly concentrated bacteria in their fecal matter in nearby areas of the seacoast (Nelson *et al.* 2008) and there were several gulls observed in/around Mill Creek during the site walk (5/4/09).

C. Awareness of the Problem of Bacterial Pollution

This section discusses the degree to which study participants and other parties involved in the Cains Brook restoration are aware of the sources and extent of bacterial contamination as well as the resulting impacts that bacterial pollution has had on the multiple uses of Cains Brook, Mill Creek and Hampton Harbor.

1. Awareness of Sources and the Extent of Bacterial Contamination

Participants expressed their awareness of a variety of sources of bacterial contamination in the Cains Brook watershed. The most commonly cited sources included wild animals (7 out of 10 interviewees), followed by septic systems in Salisbury (6/10), birds (5/10), pets and livestock (4/10 each), chickens (3/10), WWTF overflows/leakages and illicit discharges (2/10 each), and horses and detention ponds (1/10 each). Although each participant was asked to provide insight into possible/actual sources of bacteria, they tended to answer the question in different ways and to varying degrees of depth, and it is possible that some of the sources of which they are aware were not mentioned. However, these findings do somewhat parallel previously observed inputs using MST, which show that wild animals had the highest contributions (28%), and that livestock, chickens and human sources each contributed 15% or more to the total identified bacterial isolates (Jones, Landry & Edwards 2005, 23).

Despite the best efforts made to determine the sources of bacteria in the Cains Brook watershed, there is still some uncertainty. "We're still trying to track [the bacteria] down, where it may be coming from. We were kind of puzzled by some of the sources" (1 pers. comm. 11/30/07). One participant expressed concern that "we can't distinguish between human and animal bacteria too well" (7 pers. comm. 3/6/09), although MST studies clearly indicate that it is possible to identify multiples species using *E. coli* isolates (*e.g.* Jones, Landry & Edwards 2005; Tartera & Jofre 1987). However, the level of identification of source species varies among species and also among different studies, as Jones, Landry & Edwards (2005, 26) illustrate. Even though such studies have provided details on the sources and causes of bacterial pollution, participants still found that some of sources were "inexplicable" (1 pers. comm. 11/30/07). MST studies conducted in Cains Brook, Mill Creek and Hampton Harbor do, however, specify the sources (by species) of fecal bacteria (Jones & Landry 2003; Jones, Landry & Edwards 2005), but evidence in these studies is less clear on the specific locational origins of such bacteria. VRAP monitors eight sites annually throughout the watershed (Figure 4.7), providing additional information on locations of potential sources but not source species.

Study participants also indicated that there are knowledge gaps in relation to understanding potential sources originating from nearby WWTFs. The Salisbury WWTF, one participant indicated, is "another potential source that DES doesn't necessarily know about in Massachusetts" (1 pers. comm. 11/30/07). However, according to monthly measurements taken by both the State of Massachusetts and EPA Region I (Table 4.1), there was only one fecal coliform concentration violation in Salisbury's WWTF effluent between July 2004 to December 2007, measuring 100MPN/100mL (see Figure 4.6a, www.epa-echo.gov ID Number: 110024378662), where the MPN is the most likely number of bacterial cells per 100mL. The Seabrook WWTF had four fecal coliform concentration violations in effluent between August 2004 – September 2008, ranging from 18 – 15,500MPN/100mL (see Figure 4.6b, www.epa-echo.gov ID Number: 110006619622). The Hampton WWTF had three fecal coliform concentration violations in effluent between April 2004 and March 2006, ranging from 62 – 476MPN/100mL (www.epa-echo.gov ID Number: 110002320827).

Figure 4.6a. Salisbury, MA WWTF Fecal Coliform Measurements, 07/04 - 12/07

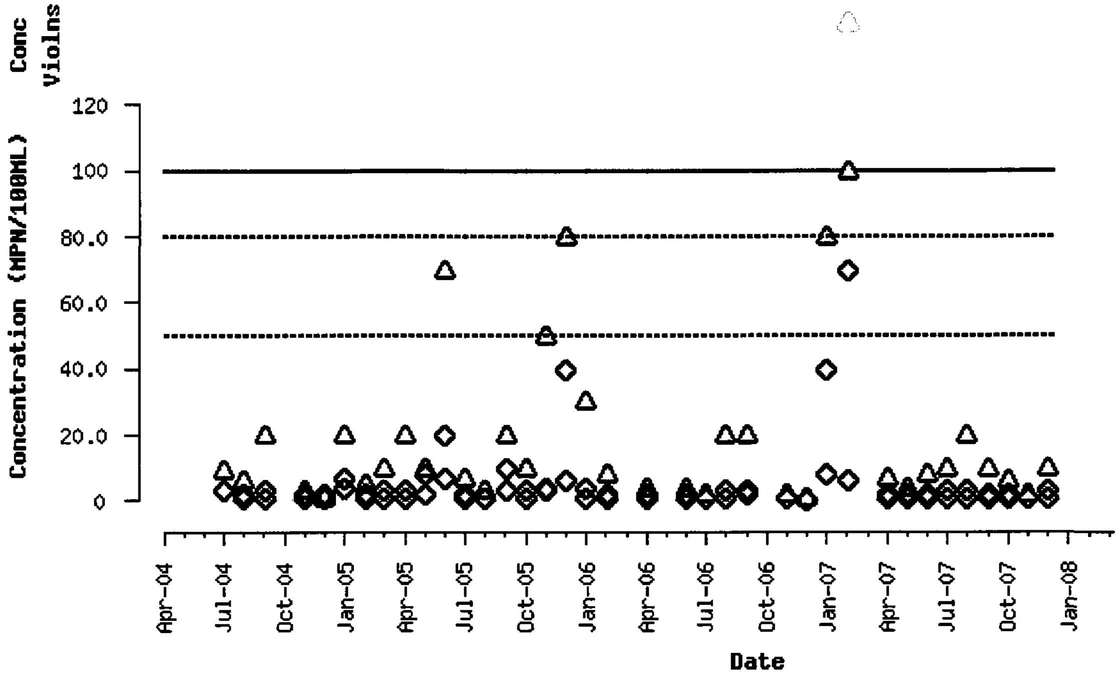
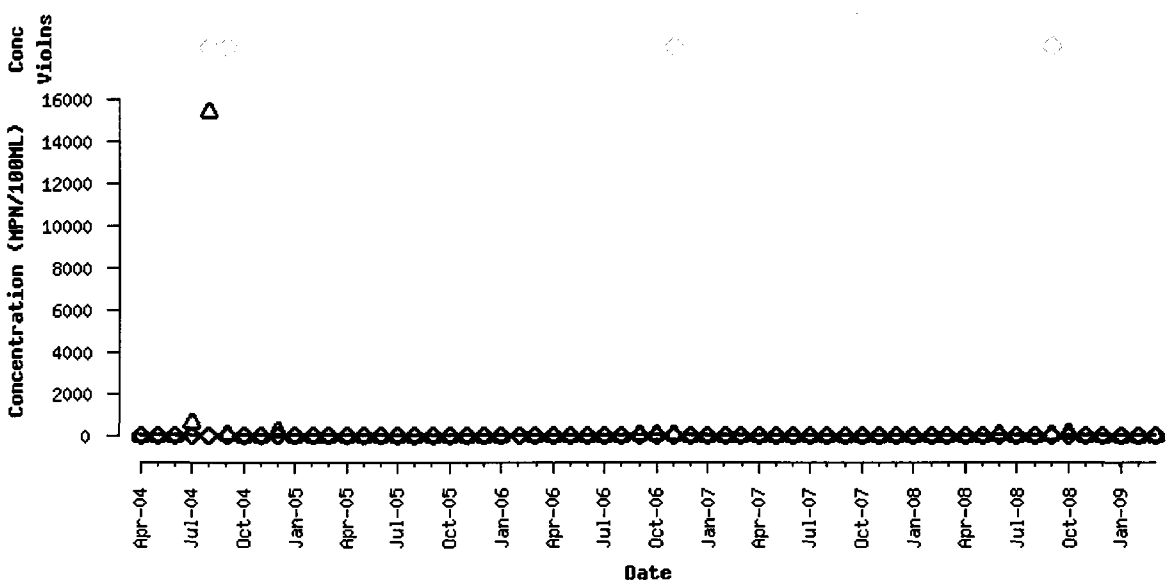


Figure 4.6b. Seabrook, NH WWTF Fecal Coliform Measurements, 04/04 - 03/09



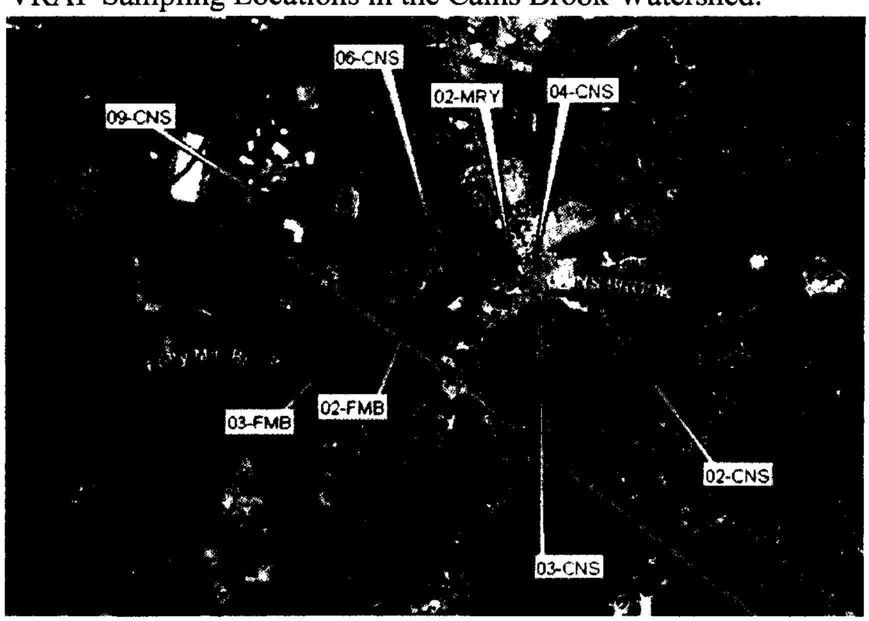
KEY

- Max Concentration Limit
- Average Concentration Limit
- No Fecal Coliform Effluent Violation
- No Fecal Coliform Effluent Violation
- Fecal Coliform Effluent Violation
- Fecal Coliform Effluent Violation

Source: www.epa-echo.gov

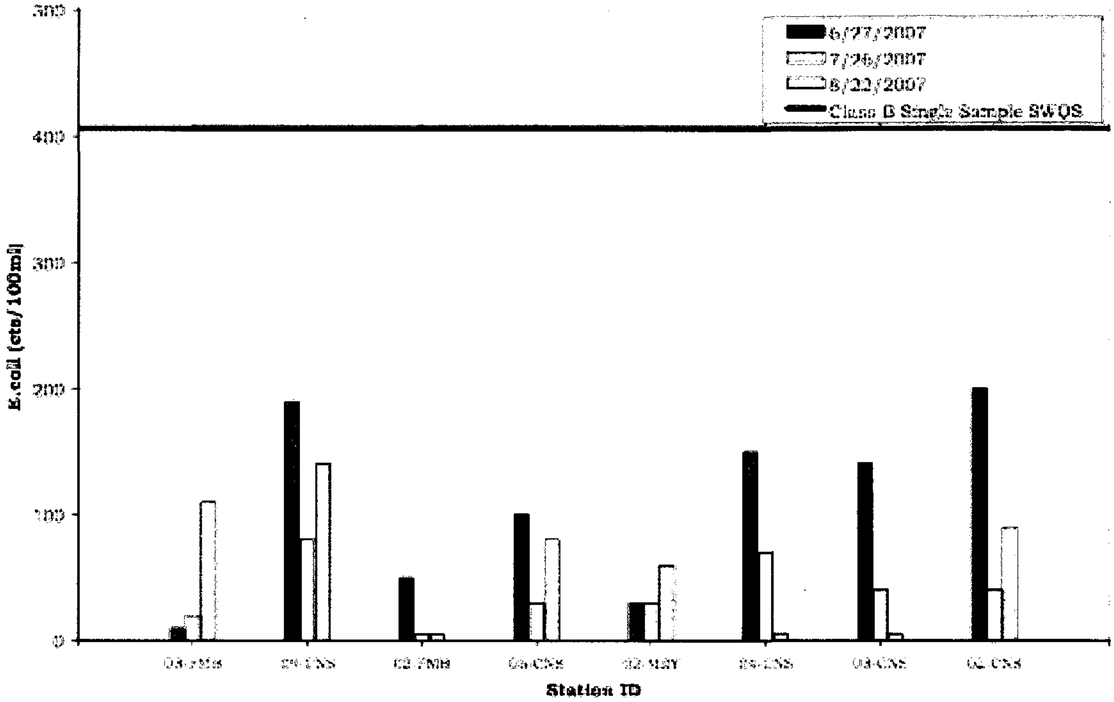
Participants indicated that the *severity of* the bacterial pollution in the watershed is a problem is a more difficult target to identify. One participant indicated that while there are clearly "bacteria in certain stretches, [Seabrook] suspects it might be in more stretches, they just don't have the test results to verify it" (1 pers. comm. 11/30/07). However, periodic sampling by VRAP at the same sample locations (Figure 4.7) from year to year, confirms the levels of bacteria (specifically, *E. coli*) in particular locations throughout the watershed (Figures 4.8a & 4.8b), although conducting sampling at more sites would shed further light on other source locations. Other participants stated that while detailed studies have provided substantial information on the extent of contamination, they are still curious as to other potential sources (2 pers. comm. 12/12/07). Another participant expressed surprise that VRAP sampling "did not seem to be finding a bacteria problem…during the summer…[but] it's possible they could be more storm-related, at times of peak stormwater discharge both from the sewer system overflows and also from stormwater runoff" (1 pers. comm. 11/30/07).

Figure 4.7. VRAP Sampling Locations in the Cains Brook Watershed.



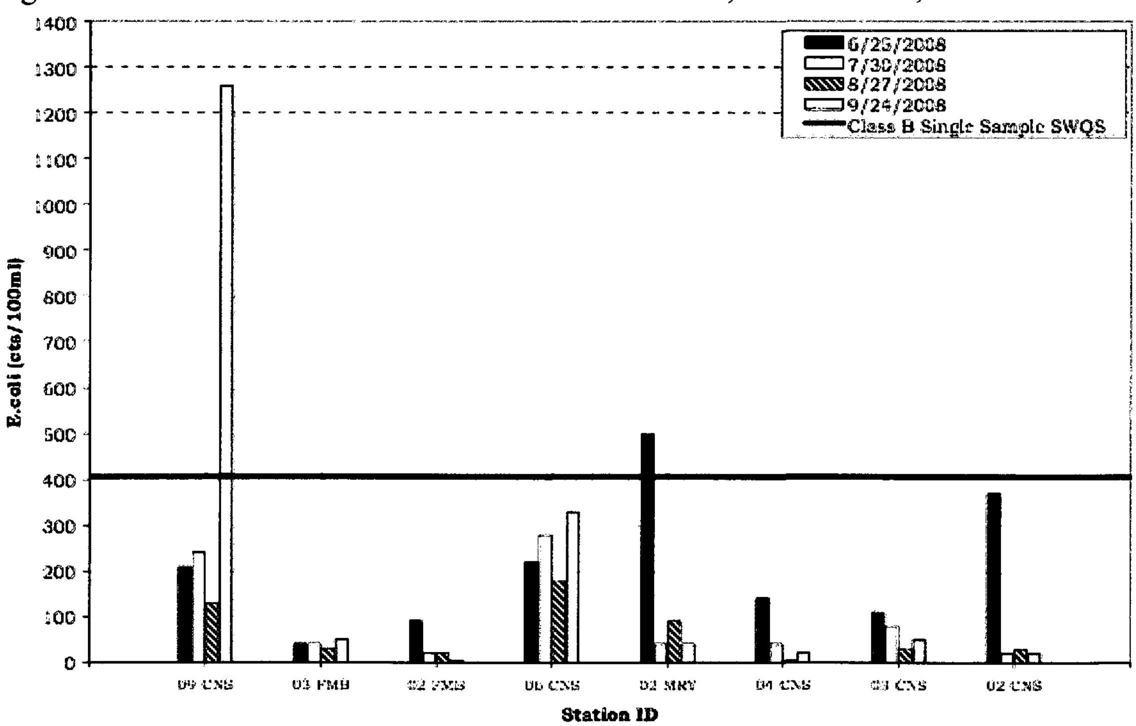
Source: VRAP 2008

Figure 4.8a. *E. coli* counts in the Cains Brook Watershed, 06/23 - 08/21, 2007



Source: VRAP 2008

Figure 4.8b. *E. coli* counts in the Cains Brook Watershed, 06/25 - 09/24, 2008



Source: VRAP 2009

2. Awareness of the Impacts of Bacterial Contamination

Four out of ten participants stated that they were aware that Cains Brook and Mill Creek are listed for several water quality impairments, including bacteria (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07; 5 pers. comm. 12/20/07; 10 pers. comm. 6/5/09). When spikes occur in bacterial concentrations, "it's worrying" (6 pers. comm. 12/19/07), one participant noted. However, two participants noted that they detected only "two instances that [bacteria] exceeded the criteria and that's when it was really, really hot in August and we had just had an algae bloom on one of the ponds" (3 pers. comm. 2/11/09; also 10 pers. comm. 6/5/09) during the 2008 sampling season. There was some indication among participants that certain reaches of Cains Brook may be more impaired than others, but that "they just don't have the test results to verify it" (1 pers. comm. 11/30/07). However, summer VRAP sampling has monitored eight sites along the length of Cains Brook and in Folly Mill Brook. The results from these studies, which analyzed 24 and 32 samples during the 2007 and 2008 sampling seasons, respectively, have measured *E. coli* counts, showing that only two samples taken during the summer of 2008 did not meet Class B water quality standards (VRAP 2009). Published reports of these studies are available online at the NH DES website: http://des.nh.gov/organization/divisions/water/wmb/vrap/cains/index.htm.

Five out of ten participants stated that they were aware of the threat posed to human health by bacteria-contaminated shellfish beds in Mill Creek and Hampton Harbor. According to one such participant, in order "to keep those shellfish healthy so that we can harvest them, we've got to try to get as many of these sources of bacteria to the Harbor knocked out as we can" (5 pers. comm. 12/20/07). "It's clear that that is a concern with shellfish being bioaccumulators [since] any bacteria in there will shut down the shellfish beds in the Harbor" (1 pers. comm. 11/30/07). Bacteria were also cited by multiple participants as being a threat to Seabrook's recreation opportunities: "If people are swimming in some of the impoundments, then there's definitely health risks with elevated bacteria levels" (6 pers. comm.12/19/07).

Study participants discussed some of the indirect impacts of bacterial pollution as well. These included economic consequences for the people that ferry fishers out to the clam flats, because tourists would likely not engage in recreational shellfishing if "people knew we had goopy creeks" (5 pers. comm. 12/20/07). Others voiced their opinion over the threat of bacterial contamination of nearby beaches, stating that "if [the beaches] somehow were shut down, like a couple of summers ago we had some beach closures due to bacteria…it was all over the news, [and] that's not good." (5 pers. comm. 12/20/07).

Two participants stated that they believe that awareness of the problem of bacterial contamination in the Cains Brook watershed is increasing among the parties involved, including NH DES, NH F&G, the New Hampshire Recreation Department, the Seabrook Police Department and the public (4 pers. comm. 12/18/07; 5 pers. comm.. 12/20/07). There was no mention of increasing attention to the issue from NH DHHS, nor from the towns of Hampton and Salisbury. The Chair of the SCC stated that "the majority of environmental offenders aren't even really fully aware of the ultimate impact of their act" (3 pers. comm. 12/13/07) in the context of allowing bacteria to enter Seabrook's surface waters. This type of sentiment was echoed by other participants (5 pers. comm. 12/20/07; 8 pers. comm. 5/22/09) as well, suggesting the need for improved education and outreach to those who would knowingly or unknowingly pollute.

Three participants also indicated that they are aware of issues that may be confounding factors that enhance the effects of bacterial pollution. These included impoundments that prohibit free-flowing patterns of Cains Brook, high amounts of impervious surface, impacts from local commerce and management difficulties with storm drain systems (6 pers. comm. 12/19/07). There was little indication from participants that these factors would be more thoroughly examined in the future, although two participant stressed the importance of understanding the local economic impacts of pathogenic bacteria in surface waters (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07).

D. Awareness of BMPs to Control Bacterial Pollution

Limiting bacterial contamination was cited in numerous instances as being the most important factor to ensure healthy and harvestable shellfish: "that…is the number one issue is that [Cains Brook] is a tributary to a shellfish growing area. Let's just address the bacteria issue and make it go away. I think there's sort of intrinsic economic value, if you will, in having clean water" (5 pers. comm. 12/20/07). Other participants expressed similar sentiments, stressing the need to clean up the "creeks and rivers and streams and ponds [to] cut down on the pollution and the bacteria, so that your clam flats can open up again" (3 pers. comm. 12/13/07).

Participants demonstrated some knowledge of specific BMPs to limit fecal bacterial contamination. These included:

- the use of periodic observations of detention ponds to eliminate gross management infractions (3 pers. comm. 12/13/07);
- deepening of the ponds to diminish algal blooms that then promote bacterial growth (3 pers. comm. 12/13/07);

- planting native plants along riparian areas to discourage wild animals, and birds in particular, from accessing and then defecating in the ponds (6 pers. comm. 12/19/07);
- removal of human WWTF effluent from the Harbor (2 pers. comm. 12/12/07);
- sweeping the parking lots of local businesses to remove contaminated trash and sediments (4 pers. comm. 12/18/07);
- mapping wastewater outfalls (1 pers. comm. 11/30/07);
- detecting illicit discharges from WWTFs and municipal sewers (5 pers. comm. 12/20/07);
- performing dye tests to determine flow patterns in the Harbor (2 pers. comm. 12/12/07);
- reaching out to Seabrook residents to encourage proper pet waste management techniques (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07); and,
- the use of a stormwater management device to control sediment input and suspension into the ponds (1 pers. comm. 11/30/07; 2 pers. comm. 12/12/07; 3 pers. comm. 12/13/07).

Participants also stressed the importance of selecting BMPs that engender a series of related, cascading benefits. For example, by cleaning up "human sewage sources from the estuary, you'd be getting rid of nutrients, you're getting rid of bacteria, viruses, and anything else that's in sewage" (2 pers. comm. 12/12/07).

E. Criteria Used to Identify and Select BMPs

During the development of the Cains Brook Management Plan (2006), an inventory was conducted for a variety of water quality parameters. "As part of the inventory, we did review the [ribotyping study]...to find some of those sources" (1 pers. comm. 11/30/07). The development of the Plan has "made a good outline of what to do [to identify] priorities...[because] there's a lot of other potential sources of problems" (1 pers. comm. 11/30/07). "I think there was a very...extensive assessment of the Cains Brook/Mill Creek watershed and their tributaries" (2 pers. comm. 12/12/07). To develop the Plan, "[they] looked at both the existing documentation...[including] a number of previous documents…and additional things that were not known about the watershed. [They] went on the [NH] DES One-Data website…[to] go through an inventory of all of [the] storm drain outfalls and NPDES outfalls [but] there wasn't a lot of documentation on all of that" (1 pers. comm. 11/30/07). In contrast, the NPDES Phase II Small MS4 General Permit Town of Seabrook Annual Report shows that all known outfalls were mapped and posted before 2008, and 27 of them were re-inspected in 2008 (US EPA 2008). VRAP data were also used to identify sources to inform decisions about which management initiatives to pursue (3 pers. comm. 2/11/09).

The documents that have outlined BMPs that are intended specifically for application in the Cains Brook restoration include, but are not limited to:

- New Hampshire Volunteer River Assessment Program: 2008 Cains Brook Watershed Water Quality Report (2009)
- New Hampshire Volunteer River Assessment Program: 2008 Cains Brook Watershed Water Quality Report (2008)
- The Cains Brook Management Plan (2006)
- Jones, Landry & Edwards (2005)

The documents that provide relevant BMPs to the Cains Brook restoration, but are non-specific to it, include, but are not limited to:

- Guidelines and Standard Operating Procedures Illicit Discharge Detection and Elimination and Pollution Prevention/Good Housekeeping (NH DES 2006)
- Nonpoint Source Management Annual Report (2006)
- Best Management Practices to Control Nonpoint Source Pollution: A Guide for Citizens and Town Officials January (2004)
- Microbial Source Tracking Guide Document (2005)

Numerous data sources (*e.g.* Jones, Landry & Edwards 2005; Cains Brook Management Plan 2006; NH DES 2007a) indicated that *human sources* of bacteria should be the primary target for management, and that they are the "low-hanging fruit that you can actually do something about" (5 pers. comm. 12/20/07). Participants also indicated that the BMPs that were being chosen to limit bacterial pollution included only those that "are going to be the most effective" (1 pers. comm. 11/30/07). Identification of specific locational sources of human-borne bacteria was cited as being of particular importance in selecting management options, "because if you've got them identified, then...that seems to be half the battle - just figuring out the particular sources [of human-borne bacteria]" (4 pers. comm. 12/18/07).

F. Extent to Which MST Data are Used

It proved difficult, based on participants' responses, to gauge the extent to which species- and location-specific sources of bacterial contamination were included in the development of management initiatives. Responses indicated that some participants are more familiar with the results of MST studies than others, although no respondents were completely unfamiliar with them. Respondents who were more familiar with the studies stated that the value in using MST to inform management is through its ability to "identify sources and pathways of bacteria and other pollutants to waterways" (8 pers. comm. 5/22/09). Respondents who were only somewhat familiar with the MST studies indicated that the studies could be used to help reduce the impacts of bacteria on shellfish beds (4 pers. comm. 12/18/07).

Participants expressed mixed opinions over the extent to which MST data are being used effectively to inform management decisions. Based on responses, MST data are currently being used in "tracking elevated levels of bacteria and other contaminants in order to establish plans for corrective measures" (9 pers. comm. 6/8/09) and that there are “very capable people working at the local and state level to make good things happen” (8 pers. comm. 5/22/09).

MST data were used in the development of the Cains Brook Management Plan (2006) and as a part of the selection process to determine BMPs (1 pers. comm. 11/30/07). The Cains Brook Management Plan (2006) addresses specific species-based bacterial sources in one location only (see Table 5, p. 20), listing bacterial counts, the most common source and associated nearby land use. These data were used then to assist in the development of the Watershed Action and Implementation Plans (Cains Brook Management Plan 2006, 46-63) (3 pers. comm. 12/13/07), but these two sections do not refer specifically to this table nor to its data. These actions would first target human fecal bacterial sources, pets and livestock, but would be more complicated for birds and wild animals based on their relative bacterial pollution contributions (5 pers. comm. 12/20/07).

E. coli samples were taken as a part of both the 1997 Impact of Septic Tank Disconnections on Water Quality in Coastal Surface and Subsurface Environments (Jones 1997) and the 1997 Cains Brook/Mill Creek Watershed Study. While these studies did not determine the species from which *E. coli* originated, they nevertheless are of value, especially when coupled with land use assessments (3 pers. comm. 12/13/07). These studies are discussed in brief in the Cains Brook Management Plan (2006, 18-19).

G. Extent and Effects of BMP Application Now and in the Future

This section discusses the BMPs that are being put into practice and/or explored for potential future application. Table 4.1 lists these practices in further detail, and is divided into categories based upon study participant responses. A similar index is included in the NPDES Phase II Small MS4 General Permit Annual Report (EPA 2008). Table 4.1 complements the NPDES 2008 Annual Report, although there is some overlap. The categories that were developed to examine BMPs for this study include:

- Stormwater Management Techniques;
- Zoning and Development Practices;
- Pet/Livestock Waste Management;
- Bacterial Source Identification and Monitoring;
- WWTF and Septic Sewer Management;
- Litter/Trash Prevention;
- Pond Management; and,
- Miscellaneous.

1. Overview

Evidence indicates that fecal-borne bacterial pollution has continually decreased, in general, in New Hampshire coastal and estuarine waters since the 1990's (Jones 2001). These water quality improvements have largely been the result of an increase in the number of homes and businesses connected to municipal WWTFs, along with improvements in the management and capabilities of said WWTFs (Jones 2001; 3 pers. comm. 12/13/07). However, only 45% of New Hampshire's estuarine waters are approved or conditionally approved based on bacterial measurements (in these areas, shellfish harvesting can only be done only 50% of possible acre-days) (NHEP 2009, 5). Stormwater runoff is the major reason why shellfish beds are closed (NHEP 2009).

The purpose of the restoration was brought into question by one participant, who worried that those involved in the restoration might be more concerned about "junk in the river…[than] water pollution" (2 pers. comm. 12/12/07). Efforts have focused largely on controlling sediment and trash inputs, for which Seabrook is installing a "BMP structure to try and trap some of the sediment and floatable trash and petroleum before it goes into Cains Pond… [but] we haven't really got any projects where we're trying, so far, looking specifically at solving the bacteria problem" (1 pers. comm. 11/30/07).

2. Cains Brook Watershed Restoration Progress

Participants expressed mixed feelings over the extent to which the Cains Brook restoration has successfully implemented practices to reduce fecal bacteria concentrations. The development of a specific plan to guide the restoration was cited as being one of the most important steps to effectively reduce bacterial contamination (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07). The Cains Brook Management Plan (2006) was described as being "a very good plan for doing [bacterial pollution mitigation]… and that certainly made a good outline of what to do" (1 pers. comm. 11/30/07). The development of the Plan allowed participants to determine priority actions and the parties that were ultimately responsible for enactment.

3. Coordination of BMP Implementation

The overall coordination of the efforts to implement BMPs was expressed by almost every interview and survey participant as having mixed results; that is, some efforts have been brought to fruition thanks to information- and decision-sharing partnerships while other efforts remain unfunded, unsupported or simply unexplored (see Table 4.1 for details). Forward progress on restoration activities has been facilitated through the diverse social interactions taking place among involved parties, including, most notably, the SCC, DPW, NH DES, and environmental consultants; these interactions were described by the Chair of the SCC as "consensus building, and in some ways, educational aspects both ways, [and] understanding the historic reasoning [of the Restoration] both ways" (3 pers. comm. 2/11/09). The process was also depicted as being a "logical process" (1 pers. comm. 11/30/07), wherein decisions are being made using the input from multiple stakeholder groups. Although there are several organizations involved in the restoration, several individuals were noted as being central to its progress, (especially the Chair of the SCC) and have had positive impacts on keeping people a part of the discussion (5 pers. comm. 12/20/07).

There have been instances in which study participants have noticed that "people are changing their behavior," but that the reasons that they may be doing this have been difficult to pinpoint (4 pers. comm. 12/18/07). Regulatory authorities were noted as having "been an obstacle in the past, [but] are finally beginning to [change]" (3 pers. comm. 2/11/09). Similarly, one participant stated that the degree of cooperation among parties "will grow [because] people are making better connections between Seabrook and the Department of Transportation because of the project" (4 pers. comm. 12/18/07), for example. Participants from NH DES expressed that they "are really committed to helping, [but] in order for them to get their money, they have to go through...this whole bureaucratic process," particularly with regard to the dredging of the ponds and creation of natural rock, pool, riffle sequences in Cains Brook (6 pers. comm. 12/19/07).

The public has had some chance to have input into the restoration, focused mostly on litter cleanup and prevention (3 pers. comm. 12/13/07; 4 pers. comm. 12/18/07). The long-term involvement of certain parties has been a positive force for implementing BMPs. As one participant indicated, "it's been fortunate for us because we've been able to keep one very competent contractor/design engineer/consultant on the project from start to finish, and we aren't intercepted with having to go back out to bid and possibly someone bids lower and [we then] have to bring someone new totally up to speed" (3 pers. comm. 2/11/09)

In contrast to these favorable developments, there was dissatisfaction expressed as to the extent to which the restoration has been successfully coordinated. Water quality monitoring efforts were described as being poorly integrated: "I am amazed there is not more coordination between the many groups doing water quality studies. It now looks like there is no coordination between VRAP and other [NH] DES studies, apparently since they have different goals, and the lines drawn between lakes, rivers and salt water, [even though] they all end up flowing to the same place" (1 pers. comm. 5/22/09). Participants also expressed their disappointment that neighboring communities have not played a bigger role in the restoration (3 pers. comm. 12/13/07). One participant stated that there is a lack of cooperation because of politics (6 pers. comm. 12/19/07).

The extent to which the public has been involved in the restoration was described as lacking: "we're not getting enough public comment…we get some turnout to the meetings, but it's not a lot. [Seabrook residents] are a little frustrated that the ponds have not been dredged yet. And they don't understand the whole big picture procedure where DES kind of mandated that we do a watershed management plan first before issuing permits and before issuing grant funding. So to the locals, I think it appears that the process is moving very slowly." (1 pers. comm. 5/22/09). Local access programming on television has been used as a mechanism to reach out to locals, but participants were unsure as to the value it has had (3 pers. comm. 12/13/07; see Table 4.1).

In addition, there is some fear that the people involved in developing management plans may not have the sufficient knowledge of the Seabrook area: "they just look in the map - they don't really understand the area" (3 pers. comm. 2/11/09). The removal of dams along the Cains Brook corridor was cited on several occasions as being a particularly contentious issue. The Noyes Pond Dam, which was breached during the Mother's Day storm of 2006, had helped to reduce sediment re-suspension and transport and also trapped floatable trash (1 pers. comm. 11/30/07). If the dam is removed, there is increased likelihood that the water level of the ponds behind it (Noyes, Cains Mill and Cains Pond) would drop substantially: "we are still sort of doing the battle with both the [NH] Coastal Program and [NH] Fish & Game that want to remove Noyes [Pond] Dam" (3 pers. comm. 5/4/09).

4. Demonstrated BMP Successes

It proved difficult to gauge the extent to which BMPs have been successful in reducing bacterial pollution, although certain BMPs seem to be having a positive effect. Stormwater runoff into Cains Brook, for example, has been reduced in commercial parking lots thanks to the installation of detention basins and man-made wetlands. "[The detention ponds] are definitely working as far as holding the water long enough to allow the siltation to fall out, catching the road salts, catching the petrochemical fallout" (3 pers. comm. 12/13/07). The result of Seabrook's installation of MS4 infrastructure to replace on-site septage treatment has also had positive water quality effects (3 pers. comm. 12/13/07). Bacterial concentrations in groundwater were observed to drop to low levels immediately following septic system removal (S. Jones pers. comm. 8/9/09). The systems that were replaced, one participant noted, "were [essentially] pretty crude effluent disposals areas" (2 pers. comm. 12/12/07).

Follow up activities to gauge the effects of BMP implementation on bacteria reductions have been sparse. The pet waste and stormwater management outreach programs have not been evaluated to distinguish pre- and post-outreach behavioral changes. Regardless of the lack of assessments, participants indicated that behavioral changes are occurring, although BMP implementation takes a long time (3 pers. comm. 12/13/07; 4 pers. comm. 12/18/07).

5. Future Needs

The current state of affairs of the Cains Brook restoration are captured well in one study participant's response:

> "Not much on-the-ground restoration work has occurred in Cains Brook as we are still waiting on the [NH] DES permit for [the] Cains Pond restoration and the Route 1 stormwater BMP chamber. The Town has acquired the rights to the Noyes Pond dam, which controls both Noyes Pond and Cains Mill Pond, and we are currently progressing design and permit applications to repair the dam, add a nature-like spillway and dredge Cains Mill Pond to have that work shovel ready for future grant opportunities." (1 pers. comm. 5/22/09).

Several members involved intimately in the restoration have expressed their desire to gradually transition ownership of the restoration from the state to the local level. This would involve giving the SCC and local consultants principle authority over restoring the collapsed Noyes Pond dam, installing an improved culvert at Route 1 and making decisions about required wetland mitigation efforts (3 pers. comm. 2/11/09).

Participants expressed their desire for increased monitoring efforts, needing "to do more testing in Mill Creek, looking at various stages of the tide, when the tide's coming in and going out, doing sampling along the length of Mill Creek to see where the concentration is the highest and trying to track down where those sources really might be. All of that's going to take real time to get out there and sample" (1 pers. comm. 11/30/07). Available funding for future projects in the restoration are uncertain, especially given the current state of the economy. One participant noted that people involved in the restoration "ended up not submitting on the first round of NOAA stimulus grants since we did not have permits filed, and there was a lot of competition, including applications by the [NH] DES Coastal Program" (1 pers. comm. 5/22/09).

CHAPTER V.

DISCUSSION

Overall, the efforts of the Cains Brook watershed restoration may be contributing to a general downward trend in the amount of bacterial contamination that is occurring there. VRAP *E. coli* sampling during 2007 and 2008 in Cains Brook show that only two samples exceeded the geometric mean of Class B water quality samples in 2008 (VRAP 2009), and one sample exceeded the geometric mean in 2007 (VRAP 2008).

Regardless of these infrequent exceedances, further efforts appear to be necessary to achieve greater reductions. "In spite of all our progress with stormwater and sewer treatment, the TMDL for Mill Creek and [the] Harbor still isn't being met" (3 pers. comm. 5/26/09), and Mill Creek remains permanently closed to shellfish harvesting because of bacterial contamination (Cains Brook Management Plan 2006). The percentage of estuarine waters in New Hampshire with enterococci concentration greater than 104 cts/100mL (which exceeds the maximum concentration for tidal recreational waters) have increased from 0.3% in 2002 to 1.0% in 2004 to 10.0% in 2006 (NHEP 2009, 18); these data include measurements in Mill Creek. Beaches have subsequently been negatively affected, with an increasing number of tidal beach advisories (as opposed to closures) occurring because of elevated enterococci levels in locations throughout the New Hampshire coast, including at Seabrook Harbor beach (NHEP 2009). The available number of shellfish harvesting days in the Hampton Harbor was only 36% in 2008, compared to other New Hampshire estuarine water that were open 50% of possible acre-days (NHEP 2009, 5). Unfortunately, the decreased availability of harvesting days is coupled with a decreasing density of harvestable-size clams in the Harbor, where abundance has dropped 40% below the long-term average (NHEP 2009, 97).

Insofar as the management focus of the restoration, its direction appears, in many regards, to be focused less on bacterial pollution mitigation than on restoration of the physical, chemical and ecological character of Cains Brook, Mill Creek and the Harbor, although it is bacteria, and not any other water quality parameter, that has consistently caused Mill Creek and the Harbor to not meet TMDL standards. Such approaches are not uncommon, as the cumulative impacts of land use at the watershed level are often poorly understood or ignored in local-level planning, especially when there is relatively little geographically specific ecological knowledge available to managers (Conway & Lathrop 2005). However, this study suggests that there is an available body of relevant data on bacterial sources and appropriate management strategies, but some misperceptions among decision makers still exist. The approach to management that is being pursued, may, however, be the best fit for current initiatives in Seabrook because substantial budget constraints and legal mandates appear to have limited the restoration to focus on the most easily attainable objectives that have far-reaching results. For example, the creation of natural-looking repeating stream sequences of small pools followed by short riffle sequences that would allow fish passage and some flood control was deemed to be one of the major goals of the restoration (1 pers. comm. 11/30/07; 3 pers. comm. 12/13/07), although it is mentioned only once in the Cains Brook Management Plan's Watershed Action Plan (2006, p. 49). This restoration objective could have a positive influence on reducing bacteria because it would limit stagnation and bacteria-promoting high water temperatures. Another mission sought by restoration participants is the maintenance of appropriate water levels in the Brook and ponds. This endeavor, too, seems primarily focused on preserving as much of the physical extent of the Brook and its ponds as possible in the face of increased infilling from erosion and construction practices.

These types of physical restoration activities may be an easier "sell" to state and federal agencies, especially given the recent financial offerings and stipulations of the new American Recovery and Reinvestment Act (P.L. 111-5) that provides resources to "shovel-ready" projects. In total, New Hampshire is set to receive some $1.3 billion for these projects, according to the website Recovery.gov. "Washington is looking for projects that can be accomplished rather quickly so that they can become poster-childs as the success of this economic stimulus package," (3 pers. comm. 2/11/09) stated the Chair of the SCC, but there is no evidence that Seabrook will receive funds specifically for restoration activities related to managing fecal bacteria. Instead, federal stimulus money appears to be slated more towards road construction and improvements, with the Department of Transportation set to receive approximately 44% of the total state recovery funding (www.recovery.gov) to pave 760 miles of road, among other projects (Gorenstein 2009). Senator Judd Gregg has appropriated some $1.6 million to the Hampton Harbor Construction project through the Energy and Water Appropriations Bill, which will provide the Army Corps of Engineers funds to dredge the Harbor and provide for the upkeep of infrastructure, according to gregg.senate.gov. Unfortunately for Seabrook, with a comprehensive plan already in place (*i.e.* the Cains Brook Management

Plan), the Town would be well prepared to implement projects using additional funding since such plans are necessary to fulfill the requirements of the Recovery Act.

Study participants and relevant literature suggest that an ideal condition for the Cains Brook system would resemble the status of the Brook in the early 1900's. Before the dawn of intense development in Seabrook, there was ample fin- and shellfishing, not to mention other recreational opportunities, available to residents and tourists alike. "What they perceive they want is certainly not restoring to the system that existed before European settlers arrived. It's restoring to...something that was in the '30s and '40s when the whole system got polluted" (7 pers. comm. 3/6/09). Within a period of five to ten years, some residents envision fishing opportunities for bass, trout and pickerel in Cains Brook and its ponds (Morse 2009). However, because of the growing population of the area that has resulted in increases in impervious surfaces and other watershed-altering practices, it seems unlikely that this idealized state will be easily, if at all, attainable.

A. Primary Reasons for Decreased Bacterial Concentrations

The primary reason why bacterial concentrations have been reduced in New Hampshire coastal areas over the long term has come as a result of improvements in WWTF operations to remove contaminants from effluent (Jones 2001; NH DES 1999). The siting of the Seabrook WWTF outfall pipe in the Atlantic Ocean is likely to have reduced the risk of contamination from overflows because of increased flushing and dilution factors, and the prevailing currents are north-to-south, transporting effluent south and away from the Harbor's outlet. As a result of the EPA case brought against Seabrook in 2004, a strict maintenance program and full-scale evaluation of the treatment processes have been enacted in order to comply with discharge permits at the WWTF (Fleming

2004). There have been two violations for fecal coliform bacteria in effluent from the Seabrook WWTF since that time (www.epa-echo.gov). Participants in this study indicated, in a few instances, their familiarity with the value of the siting of Seabrook's WWTF outfall in the Atlantic Ocean, although it was not discussed to the same extent as the potential threat of contamination from the Hampton and Salisbury WWTFs. This threat may be a misperception, however, since a total of only four violations occurred at both the Salisbury and Hampton WWTFs during a three- and two-year sampling period, respectively (www.epa-echo.gov).

With the goal of having 100% of possible acre-days in New Hampshire's estuarine waters open to shellfish harvesting (Cains Brook Management Plan 2006; NHEP 2009), bacteria monitoring efforts in and around Cains Brook and Mill Creek have increased in the last 10 years, particularly as the various uses of surface waters have been further classified according to EPA requirements. Regular annual VRAP sampling along Cains Brook serves to enhance the efforts of other tests performed in and around Hampton Harbor and provides a scientifically sound, cost-efficient means of keeping restoration participants informed. MST studies, while not conducted at regular intervals, have shed substantial light on bacteria sources, particularly when coupled with land use assessments, site walks and information gathering sessions with the public. These data are clearly being used in determining which BMPs should be followed and also which sources of bacteria should be targeted first, but the degree to which these data are being used is somewhat ambiguous. This study suggests that data on species- and location-specific sources and causes of fecal bacterial contamination may not be being utilized to their fullest extent. The results of interviews, surveys and a review of relevant literature show that there was has been minimal attention to specific initiatives to directly limit bacterial pollution. Instead, other types of BMPs are being recommended and installed that, as participants indicated, will hopefully provide secondary benefits in the form of bacteria reductions. These BMPs include, for example, dredging and deepening of Secord's and Cains Pond, installation of the Route 1 stormwater chamber, and encouraging land use conversions, such as converting the land around Noyes Pond to a conservation easement. These actions are the most observable priorities of the restoration, as attention from local media sources indicates (*e.g.* Morse 2009; Chiaramida 2008a). However, two of the major restoration investment areas do seem to be targeting bacteria reductions directly: outreach activities led by the SCC and NH DES and improvements in stormwater management.

1. Outreach Activities

Outreach activities to local residents and business owners have likely contributed to a reduction in the amount of contaminants in stormwater runoff and even direct inputs into surface waters. Business owners and local residents alike have been given numerous informational messages using multiple types of media about how to properly reduce the impacts of pet waste, litter and stormwater pollution (3 pers. comm. 2/11/09). For example, the Seabrook DPW has recently distributed fact sheets on stormwater management to 385 local businesses that have on-site stormwater infrastructure (EPA 2008) (Table 4.1). That kind of information is also available at several Seabrook locations, including the Town Hall, Community Center and Library, in the form of free brochures, posters and short educational movies.

Other specific outreach-based actions to reduce bacterial contamination are less tangible, although sufficient funding may be difficult to secure at this time. Since the Claremont School Decision, an important legal case that took place during the 1990's, Seabrook's annual budget has been drastically reduced, affecting available monies for projects deemed non-essential by the state (3 pers. comm. 12/13/07). Funding through the Recovery Act for outreach activities seems unlikely at this time, based on the proposed expenditures of Recovery Act funds, as discussed previously.

2. Stormwater Management

Seabrook has taken on a variety of initiatives to reduce the impact of wastewater-transported bacteria, in part because of the strict requirements of the NPDES Phase II requirements. After providing the first NPDES Stormwater Management Plan in 2003, Seabrook has moved forward in the detection and elimination of illicit discharges, mapping the locations of detention and retention ponds, improving BMPs at Town facilities, cleaning out approximately 400 catch basins and educating citizens using doorknob hangers (EPA 2008; Table 4.1). However, "NH DES subsequently acknowledged that illicit connections are regulated point source discharges rather than nonpoint discharges" (EPA 2003, 7), which have proven to be much harder to source.

There has been a concerted effort to encourage public involvement in activities such as litter cleanups, pet waste pick-up campaigns, displays of BMP posters at community events, encouraging volunteer assistance with monitoring, and promoting an "Adopt-a-Stream" program for locals (EPA 2008; Table 4.1). Altogether, stormwater management techniques seem to be being utilized as one of the low hanging management fruits that study participants described as critical to the early steps of the restoration. An important finding that should be taken into consideration for future stormwater BMP installations and upgrades comes from Jones (1998), which suggests that both the type and condition of any stormwater management system are factors that influence the system's effectiveness at removing bacteria, where some systems consistently remove contaminants and others release higher concentrations in effluent than influent.

There are a variety of stakeholders involved in stormwater management, from the federal level through the U.S. EPA, to the state level through NH DES, to local Seabrook town departments, including the DPW and SCC, as well as contracted engineering firms like Earth Tech Inc. and Waterfront Engineers Inc.

B. Continuing Development Pressures

Despite recent improvements in water quality, the need to monitor and implement BMPs to control bacterial pollution is great, particularly in light of growing development pressures. Seabrook officials in several Town departments are extremely busy dealing with the rapid pace of growth there, and as the Chair of the SCC noted, "Seabrook has been informed by Office of Energy and Planning that for towns throughout New Hampshire, Seabrook is probably the most busy Planning Board throughout all the towns because of the development we are enduring because we are a border town of Massachusetts" (3 pers. comm. 2/11/09). The Town is under a strong obligation to get their regulations in order in the face of increased residential and commercial development: "We are scrambling to try to get things back together. Look out, it's headed your way, get your regulations in order to protect yourself before [the development] hits you. Because [Seabrook is] a summertime tourist destination, and now becoming a wintertime retail marketing destination, the pressure on Seabrook by the big developers that all want their piece in the action is really becoming almost overwhelming" (3 pers. comm. 2/11/09).

Public health issues remain at the forefront of the decision-making agenda because of increased human uses and resultant potential exposure to pathogens and other contaminants remains high, and because it is a main thrust of the requirements of several policies. "The real concern is [the] public health threat from the human pathogens. That said, it's not a healthy environment to have fecal material floating around in the water where it shouldn't be" (2 pers. comm. 12/12/07).

The economic and non-economic impacts of having polluted water are an important and ever-present driver of the restoration. "There's sort of intrinsic economic value, if you will, in having clean water. From both the human health and management perspectives, human-borne fecal bacteria require the most attention because of the increased risk of infection. Intra-species pathways are a more common route for disease transmission. Humans: that's [the] priority, you need to deal with that first, number one" (5 pers. comm. 12/20/07). Other studies corroborate the fact that human wastes may pose a greater threat to human health than non-human ones (NH DES 1999). Seabrook is not, however, the only town on the seacoast that is growing. What that means for Seabrook is that it will need to continue to be aware of possible human-borne fecal inputs that do not originate from within its borders.

As development pressures increase throughout the watershed, the riparian zones around Cains Brook have gradually been reduced. At no more than 20 ft on average

(VRAP 2009), both banks of the Brook are subject to an increased likelihood of contamination. These riparian areas can serve as buffers against surface runoff that may contain fecal bacteria, but most of the natural shoreline buffers in the watershed are far below the required minimum of 50 ft as stipulated by the Comprehensive Shoreland Protection Act (NH RSA 483-B) (VRAP 2009; Site Walk 5/4/09). Shoreland buffers have been noted as being "the single most effective protection for surface waters in New Hampshire" (Lakes Management Advisory Committee and the Rivers Management Advisory Committee 2008, 8). Some organizations, such as the Audubon Society of New Hampshire, have recommended even larger buffers than the 50 ft standard. They recommend buffers be no less than 100 ft, which is "a reasonable minimum buffer width under most circumstances" (Chase, Deming & Latawiec 1995, 23). However, they also stress that a minimum buffer width should be determined based on several local factors, including the distance between the surface water and the land from which the waterbody is being buffered, but that wider buffer widths are generally more effective than narrower ones (Chase, Deming & Latawiec 1995).

The requirements of the Comprehensive Shoreland Protection Act do not apply to buffers around small order streams like Cains Brook. Because of changing land use practices, "you're removing the vegetated areas that removed the nutrients [and bacteria] in a natural way...so you are removing the filter" (7 pers. comm. 3/6/09). The SCC has posted a recommendation on the Town website that 100 ft buffers provide "a pollutant removal rate of at least 60%, which is considered an acceptable level of protection for water quality" (SCC n.d., 1). This document also includes information on the quality and types of buffers that should be established, but does not provide information on how to construct or encourage buffer development, nor does it provide external resources.

In addition, wetland permits have been granted that have resulted in the filling in of wetlands that can aid in filtering of bacteria, sediment and trash. Required mitigation efforts under NH RSA §482 (Fill and Dredge in Wetlands) have not proceeded in a manner that would be beneficial to the restoration, as three participants indicated. The Chair of the SCC provided some indication as to why this progress is impeded from the standpoint of the usage of available NH DES funding:

> "DES [is] agreeing to allow salt marsh restoration as mitigation for [a development] site [that is] impacting a little over an acre of freshwater wetlands. To be able to transfer from freshwater wetland to saltwater does not logically make sense to me, the major reason because there are a lot of grants available for salt marsh and saltwater restoration. There are very few grants, they are few and far between, for restoring freshwater [wetlands]. And the competition for freshwater restoration is phenomenal compared to the competition for salt marsh restoration in the state of New Hampshire" (3 pers. comm. 2/11/09).

Participants in this study discussed factors that are likely to cause increased bacterial pollution in the Cains Brook watershed. These included: increases in impervious surfaces (already well beyond levels that suggest significant negative impacts to water resources); poor management of WWTFs; a lack of vegetated riparian zones along the Brook; increased sedimentation that has resulted from continuing development; aging infrastructure, particularly of the Seabrook municipal sewer system; and heavy rainfall events. Discussion of these bacterial load-intensifying factors was fairly minimal, but that does not necessarily signify a lack of knowledge. Based on the total time of the interviews and the depth to which participants were questioned, it is unlikely that the participants would have recalled all of the known factors that influence bacterial contamination of surface waters. Those most closely associated with the Cains Brook restoration seemed well aware of the indirect threats that likely increase bacterial loading in Cains Brook and Hampton Harbor. What they acknowledge that they are unaware of, however, is the extent of the direct threats posed by pathogenic bacteria, probably due to a lack of sufficient data and resources. There was no discussion during interviews or in surveys of the number of illnesses that may have occurred or might occur due to contaminated shellfish and/or beaches. A literature review did not reveal information on the instances of illness caused by fecal-borne bacteria in New Hampshire surface waters, which is a possible gap in information-sharing practices.

C. Social Processes

The Cains Brooks watershed restoration is still in its infancy in some regards. The idea to clean up the watershed originates from a longtime Seabrook resident, Henry Felch, who came up with the idea in 1996, when he was the Chair of the SCC (Morse 2009). Much has happened since that time, and there is new leadership that is moving the restoration forward. Seabrook residents and officials have served as the leaders of the restoration (1 pers. comm. 11/30/07), but assistance has also been provided by state officials, university researchers, local businesses and media, including local access TV programming, newspapers and websites (Table 4.1). Financial assistance has been provided through SCC funds (via the Seabrook Conservation Trust), the New Hampshire Estuaries Program, state and federal grants, and payments from local businesses, including Lowe's, Kohl's and Home Depot. The results of this study suggest that many of the parties involved have been given opportunities to contribute their knowledge, skills and funding to the restoration. Unfortunately, cooperation from Salisbury and Hampton could stand to be enhanced since there is the likelihood that bacterial pollution may emanate from leaky septic systems in Salisbury, and septic system pollution and the occasional problems with WWTF effluent both Hampton and Salisbury may contaminate the Harbor, which is the area of concern shared by all three communities. The policy sciences analytical framework suggests that uniformity of decision-making among parties is critical to the success of natural resource management, wherein processes must be applied without discrimination (Clark 2002). Clark also stresses that cooperation should not be sought through coerciveness, but instead should allow decision making to occur free of pressure, threats and inducements that could contribute to bias (2002). The restoration does not appear to be using coercive measures to enlist the participation of absent parties.

The choices made to determine which BMPs to implement have come from a variety of sources, but overall, there seems to be a desire to select those BMPs that have a history of demonstrated success as opposed to those that are less well researched. Study participants described those members of the Cains Brook restoration who are considered its leaders as having had a long history of involvement with many Seabrook affairs (1 pers. comm. 11/30/07). This has been a key tenet of the restoration itself, in that a few well-connected and passionate individuals have continually driven the process forward. The loyalty and skill of decision makers is an important component to derive long-lasting results (Clark 2002), and it has been highly apparent that some of the restoration's most involved individuals are both loyal to its cause as well as highly skilled in preparing restoration plans, gathering support from town residents, and working with other officials. Authoritarian decision making has not been evident, and parties not closely connected to the restoration have been encouraged to play a more active role in it (4 pers. comm. 12/18/07). More specifically, through collaborative planning initiatives, the available budget for projects has increased substantially. The first major restoration investment came in the form of $225,000 appropriated by Seabrook townspeople to dredge Secord's Pond in 2000 (3 pers. comm. 12/13/07). Shortly thereafter, $45,000 was devoted to the development of the Cains Brook Management Plan (2006) made possible through NH DES a watershed assistance grant through the NHEP (3 pers. comm. 2/11/09), although that is less than the amount noted in Governor and Executive Council Minutes from June 13, 2007. As of June 2009, the Plan has been revised thanks in part to a NH DES grant, but it has not yet been given final approval by NH DES. Additional financial assistance for the restoration has come from local developers, in part as a requirement for mitigation from construction impacts.

One of the factors that has likely served to move the restoration forward is the degree to which involved parties are familiar with relevant studies. One of the quoted leaders of the restoration stated that she is "quite familiar with virtually all of [the studies] that have been printed, and participated in...at least half a dozen of them" (3 pers. comm. 12/13/07). Since that time, she, and other restoration leaders, have continued to participate in some of the studies measuring bacteria concentrations, although no new MST studies have been conducted. This familiarity with study data has enhanced the degree to which decisions have targeted specific sources and causes of problems in the watershed, including, but not limited to, fecal bacterial pollution. BMP research, design and installation has been largely guided by several SCC engineering consultants (including Waterfront Engineers, Inc., Appledore Engineering, Inc. and Earth Tech, Inc.).

1. Public Involvement

Public involvement has been a critical piece to the restoration puzzle, although the extent to which it has driven management directions seems limited. The most obvious public involvement has been in the form of assisting in Cains Brook litter cleanups and storefront cleanups. Storefront sweeping is mandated according to a Town litter ordinance (EPA 2008), but has been encouraged by restoration leaders using stormwater management brochures, doorknob hangers, a short educational video and at least one public meeting (held August 14, 2006) (Table 4.1). Study participants agreed that engaging the public for this type of watershed-scale approach to management is an important step in order to "to provide public access to the Brook, and to…have good fish passage and to have boating occur there again" (5 pers. comm. 12/20/07). There was less discussion of how to get the public involved in measures to reduce bacterial loading than for other types of management initiatives, which again indicates that reducing bacteria may not be a priority to all of the stakeholders involved in the restoration, even though it is one of the primary goals of the Cains Brook Management Plan (2006). This finding may be indicative of the difficulty inherent in educating both managers and the public on issues of bacterial pollution mitigation. Like so many other natural resource management issues, reducing surface water bacteria is a complex and multifaceted issue that requires sound science, outreach and education, knowledgeable and determined decision makers, flexibility and realism, and sufficient budgets (Clark 2002).

2. Delays in Implementing BMPs

A critical setback to successful implementation of BMPs has been the result of delays in getting impairments officially listed and recognized by NH DES. This is particularly relevant to the dredging of Cains Pond, which has been pursued as a component of the restoration for several years. The dredging has been sufficiently funded through SCC funds and assistance from local developers and state and federal grants, design plans have been made and a dredge permit acquired, but the dredge has not yet occurred because of the long time it has taken for listing of the impairment of Cains Pond (1 pers. comm. 5/22/09; 5. pers. comm. 12/20/07) (Table 4.1). Some residents of Seabrook have expressed their personal frustrations that this has not yet come to fruition, although officials have shied away from implementing BMPs without a satisfactory plan in place: "you can spend all the money just dredging the pond and have it all done and over [but] we can't guarantee that it's going to restore the pond. Whatever is filling it up right now, is going to fill it up again. You'd do much better to seek grants, to stretch your money out, and do an entire watershed management plan. Let us study the watershed, find out where the good parts are, where the tweaking is [needed], and where the bad parts are, and then we'll know where to focus the money" (3 pers. comm. 12/13/07). This slower but more systematic approach to BMP implementation was described as being important to the long term sustainability of the Cains Brook watershed by several participants. However, a key indicator of the overall success of the decision-making process is the amount of time it takes to address problems once they have been raised, with substantial delays being emblematic of a poorly performing process (Clark 2002).

3. Coordination with Surrounding Towns

A critical roadblock that has been encountered in the Cains Brook restoration is the lack of coordination with the surrounding towns of Hampton and Salisbury. The "small-town rivalry" that exists between Seabrook and Hampton has limited the ability for restoration leaders to communicate effectively, and there does not appear to be any substantial effort to try to overcome this barrier (3 pers. comm. 12/13/07). Working with Salisbury is made difficult because it is across a state border, in which case monitoring for potential effluent releases and other bacterial sources is prohibitive without consent from Salisbury. There is some indication that NH DES has been in contact with Salisbury officials, but it is not at a meaningful level (5 pers. comm. 12/20/07). The Cains Brook Management Plan (2006) indicates that one of the biggest threats to bacteria could be from Salisbury's septic systems which are governed by a zoning by-law. The by-law requires site plan reviews of drainage, stormwater runoff and water quality impacts of all new development, *excluding* single and two family homes, which are common in the portion of the Cains Brook watershed in Salisbury. This study did not uncover any data specific to the concentrations of bacteria that are being released by these septic systems, however, there is an ongoing sewer and water project along Rabbit Road in Salisbury that began in May of 2008; the northern portion of Rabbit Road is situated within the Cains Brook watershed. This project, guided by the Town of Salisbury Department of Public Works, Sampson Engineering and Albanese Brother, Inc., is in the process of installing about 20,000 linear feet of sewer main/laterals and replacing septic systems (www.salisburyma.gov/PBCC/Pbsewerconstruction.html; Chiaramida 2008b). Salisbury residents are only required to connect to the sewer if they have failing septic systems, but voluntary connections are encouraged. The project is slated to take approximately two years to complete. This project has the potential to reduce bacterial contamination in the Cains Brook watershed, although the extent to which it may do that is unknown.

D. Recommendations

This section will provide recommendations for possible future research and management activities for the Cains Brook watershed restoration. They will focus primarily on bacterial pollution reduction strategies, but their successful implementation should have positive secondary effects, including sedimentation control, organic matter and other contaminant control and reduction in eutrophication processes. Since many recommendations specific to this project have already been made, this analysis will not repeat said recommendations, but seek to provide new ones or build upon old ones. The order of listed recommendations is not intended to imply their priority.

There are numerous entities that provide assistance to towns like Seabrook in the form of online tutorials, in-person site walks and analyses, and even BMP field testing. The International Stormwater BMP Database project has collected over 340 tested BMPs with associated bacterial counts to illustrate the effectiveness of BMP installation (Clary *et al.* 2008). The UNH Stormwater Center, in addition, designs and constructs stormwater management BMPs, and is available as a unique resource to many communities in need field testing. The Center has published recommendations, accessible online, on how to manage runoff (*e.g.* Peterson, Stone & Houle n.d.). Much of the Center's funding is provided through NOAA and the Cooperative Institute for Coastal and Estuarine Environmental Technology, so the associated costs to Seabrook could be minimal.

BMPs are intended to limit NPS in three ways: by minimizing the sources of pollutants in the first place, by reducing pollution transport downstream and by intercepting or remediating pollutants before they reach a sensitive location such as shellfish beds (NH DES 2004a). Previous recommended BMPs sought to use almost exclusively physical treatments including swales and sedimentation basins (Jones 2001), although the ability of structural BMPs to reduce bacteria is largely subject to local variables, with the result that the effectiveness of BMPs varies widely (Clary *et al.* 2008). This study finds that new, alternative methods are being explored and should be further explored. Some of these methods may be just as effective, if not more, at controlling fecal bacterial contamination.

Much of the literature available on BMPs to reduce bacterial pollution tends to focus on physical, chemical and biological methods to reduce contamination. However, this view may be shortsighted, as alterations in human behavior can result in longer-term and wider-scale use of best practices. Therefore, this study includes alternative methods such as education and outreach campaigns in its list of suggested BMPs.

1. Encourage Management by Local Entities and Rectify Misperceptions

Seabrook citizens and officials are already largely at the helm of the Cains Brook restoration, although conflicts with adjacent towns and state departments have led to some unresolved issues. The NH Department of Transportation (DOT) oversees changes to road and highway infrastructure and has made it difficult for Seabrook to complete installation of BMPs along the Route 1 corridor, particularly at Cains Pond, due to ownership rights of the land bordering the road (3 pers. comm. 12/13/07). The NH

DOT Bureau of Rail and Transit has stalled efforts to mitigate the impacts of certain land use practices on the abandoned railway that runs parallel to Route 1 and the Dam Bureau has made it difficult to move forward with restoration of the destroyed Noyes Pond dam because it is on private property (3 pers. comm. 2/11/09). By allowing local entities such as the SCC and DPW to have principle authority over these locations and structures, Seabrook may be able to more effectively gather public input that will result in management decisions that have broad public support; evidence supporting this transfer of authority comes from two study participants' general concern that state and federal entities are too far removed, geographically and conceptually, from Seabrook's affairs. However, certain roadblocks to successful implementation of the Cains Brook Management Plan (2006) seem inevitable (3 pers. comm. 2/11/09). Therefore, in cases where progress is hindered by politics or merely a lack of will to cooperate, oversight by officials from the EPA Region I office may provide assistance, especially since some members of the restoration already have a working relationship with EPA.

There appear to be a set of critical misperceptions regarding bacterial pollution in and around the Cains Brook watershed. Specifically, the effectiveness of various stormwater control devices is poorly understood, as is the perceived threat of contamination from WWTFs. Evidence indicates that stormwater control devices, including retention ponds along Route 1, are successfully limiting bacterial concentrations, according to VRAP data (Figures 4.8a & 4.8b). The number of NPDES permit violations from three nearby WWTFs is not substantial (eight violations in total from all three WWTFs over a period of five years April 2004 to March 2009, although some data was not reported), and does not correspond temporally to two major recent storm events, suggesting that management of these WWTFs is mostly within acceptable standards. The threat posed by pathogenic bacteria to human health was a common theme in nearly every interview and survey, but specific details of this threat were rarely divulged. Participants stressed that bacteria levels in the watershed were worrisome, although the extent to which they could explain the association between bacteria levels and limitations on various designated uses was insubstantial. Educational efforts should be undertaken to dispel these misperceptions because decision makers need to be sufficiently aware of which interests are more widely shared than others (Clark 2002), and misperceptions can lead to poor decision-making.

2. Foster Increased Involvement by Local Citizens and Businesses

Some efforts are being made to reach out to local Seabrook residents and businesses, but further investments would likely prove valuable. Currently, the major public outreach efforts are centered around litter cleanup, and pet waste and stormwater management practices (Table 4.1). Future engagement may be best directed at private land use activities such as using runoff control techniques including vegetated buffers and berms and proper manure spreading and storage methods (Jones, Landry & Edwards 2005). In addition, utilizing the expertise and outreach capabilities provided by extension programs at UNH, Sea Grant, the Piscataqua Region Estuaries Partnership (formerly, the NHEP), and NH DES, among others, may serve as catalysts to excite and inform more members of the public to encourage them to participate in the decision-making process. As third party consultants, these organizations are often seen as "honest brokers" whose objective input and guidance does not supercede the decision-making authority of the public. The policy sciences framework suggests that it is important for the public to be involved in decision-making processes in inclusive ways, and designations of authority must be appropriate to the task at hand (Clark 2002).

3. Coordinate Better with Surrounding Towns

There appear to be hurdles associated with implementing BMPs in coordination with surrounding towns. However, it is also important that Seabrook consider the likelihood that activities that take place in Salisbury and Hampton are substantially less likely to influence fecal pathogen levels in Cains Brook than are activities that take place within Seabrook. That perspective would naturally make it difficult for members of the Cains Brook restoration to convince Salisbury and Hampton to assist in efforts to clean up Cains Brook and have Mill Creek meet TMDL standards. Since partnering on a larger scale where the Harbor is the focus could serve to bolster the efforts of all three towns, future endeavors might seek to invite town officials, such as members of Conservation Commissions, Planning Boards, County Planning Commissions and Public Works Departments, and even town residents to consensus-building, town-hall style meetings where problems can be accurately specified and watershed-scale solutions developed. This process may again be best facilitated through the use of third-party extension networks. Ultimately, some sort of binding agreement might be developed (such as a MOU) or even a wider Hampton Harbor watershed management plan) that would require each party to continue to play its part in the restoration, monitoring and other resource management arenas. Similarly, the development of a Hampton Harbor interstate watershed commission would encourage participation from all of the communities within the larger Harbor watershed. This process would involve bringing people together to conduct a thorough analysis of relevant regulations and ordinances in effect in each town. "When individuals or subgroups are unable to resolve their conflicts on their own and there is increasing potential for damage to the public order, the larger community must become involved" (Clark 2002, 75).

4. Create an Icon that Symbolizes the Restoration

When successfully done, people learn to associate icons with ideals and that becomes a powerful reminder of the efforts that a group is undertaking. Currently, the restoration has no recognizable symbol with which people can identify. One study participant suggested using a soft shell clam as an icon (3 pers. comm. 12/13/07) because of the intimate connection and history that Seabrook residents, as well as tourists, have with shellfishing opportunities there. Outreach materials such as the stormwater and pet waste brochures and posters could be embellished with such a symbol in future mailings and outreach events at an insubstantial extra cost to Seabrook.

5. Improve the Seabrook Website

The Seabrook town website (http://www.seabrooknh.org) is regularly updated for its content, but the design, usability and extent of available information are limited in some respects. Recommendations for future improvements include the dedication of one page exclusively relevant to Seabrook residents and businesses on the Cains Brook watershed restoration. As of August 2009, the only relevant restoration documentation on the site includes the Cains Brook Management Plan (2006), a PowerPoint© presentation seeking volunteers to aid in the restoration of Cains Brook, a brochure on the effects of wetland filling, a brochure on wetland buffers and the pet waste brochure (http://www.seabrooknh.org). Updating the site to provide more content would provide the critical information necessary to inform the public and might highlight such topics as pet waste cleanup, manure storage and management practices, the use of vegetative buffers near surface waters for residents as well as businesses (including buffer installation methods), and promoting the adoption of conservation easements, along with associated points of contact. The site could also provide links to view bacteria source tracking data gathered by UNH JEL and VRAP, although it would be best to avoid including too much technical information. The site should encourage Seabrook residents and businesses to participate in restoration activities such as litter cleanups and sidewalk sweeping, beyond the simple inclusion of a downloadable file. These types of activities could be highlighted under a "success stories" heading to encourage continued, and even increased, attention to and participation in the restoration.

6. Monitoring

Monitoring for potentially disease causing bacteria in the surface waters of Seabrook and its vicinity is critical to the long-term goals of the Cains Brook restoration and to Seabrook's economy and the health of its residents.

i. Continue to Use Species-specific Tracking Methods

MST methods that use species-specific markers are a valuable tool to identify bacteria sources, but only through periodic testing can *new* sources be targeted and eliminated. Several different methods of MST have been developed in recent years, but most are still considered experimental (Griffith, Weisberg & McGee 2003). Determining which method to use must account for a number of factors, including the questions being examined, the scope of the problem at hand, availability of resources (financial, laboratory equipment, cost), time, and expertise (Meays *et al.* 2004). Ribotyping is commonly perceived as being expensive, but the benefits of using MST to target and eliminate sources usually outweigh the time and costs of simply collecting and performing *E. coli* analysis, which does not shed light on species-specific sources (S. Jones pers. comm. 8/9/09). Seabrook may have limited financial resources because of budget cuts following the Claremont School Decision, but investment in a MST study, when coupled with VRAP *E. coli* detection and land use assessments is likely a more rewarding expenditure of resources (Noble *et al.* 2003; S. Jones pers. comm. 8/9/09), especially given that samples are ribotyped in a very selective manner.

Experts who have conducted MST studies in Seabrook in the past continue to be familiar with and involved in restoration activities (3 pers. comm. 2/11/09) so utilizing their available resources should not be problematic. The SCC might seek to enlist the support of the large commercial retailers to supplement its bacterial source detection monitoring efforts and should continue to partner with JEL and NH DES to draw upon their source tracking capabilities and funding opportunities, respectively.

ii. Use Viruses as Secondary Indicators

Among a long list of proposed indicators of fecal contamination, including fecal streptococcus, acid-fast bacteria, sulphite-reducing bacteria, and bacterial phages, none has proven to be a perfect candidate because of "differences in the survivability of various pathogens and the possibility that some bacterial indicators multiply in environmental waters" (Geldreich 1996, 318). Fecal coliforms are the common indicator used to detect pathogens in shellfish growing waters, while *E. coli* remains the choice for detection of fecal contamination that results from human-generated effluent (Feng, Weagant & Grant 2002). However, viruses are often also found in conjunction with bacteria in fecal matter in surface waters, and the pathogenic strains can cause illness through transmission via primary and secondary recreation as well as through ingestion of shellfish. It is possible that many viruses may be present in a water body but only a few can be detected by cultivation methods that distinguish viable from nonviable organisms (Scott *et al.* 2002). The common fecal bacteria indicators are not necessarily adequate for the detection of human pathogenic viruses (Noble *et al.* 2003), but MST methods have been developed to detect both types of pathogens in fecal matter. Unlike those used for bacteria, however, the MST methods used to detect viruses are not dependent upon the use of a genetic fingerprint library (Noble *et al.* 2003). The detection of viruses, such as the *Bacteroides fragilis* bacteriophage, which has been detected in human wastes but not in various animal wastes, could prove to be an advantageous method for tracking human fecal pollution, and their presence in the environment is significantly correlated to the presence of human enteric viruses (Scott *et al.* 2002). One recommendation for improved source identification would be to conduct additional MST using viruses as indicators, because comparative studies aid in confirming previously detected sources, finding new ones, and allowing resource managers to make reasoned decisions about which sources are the most critical targets.

iii. Use of Models and GIS to Predict Bacteria in Runoff

Predicting the bacteriological content of stormwater runoff can be aided by the use of models that account for rainfall, temperature (Walker *et al.* 1990), location, stream flow and temporal variations. NH DES does employ a mass-balance model (the Hampton Beach runoff model) to better understand contributions from "natural" sources (*i.e.* wildlife and birds) to Hampton Harbor, but this occurs only during dry weather conditions, and is based on several assumptions, including:

- "the only dry-weather bacteria sources are the WWTF and other permitted facilities, boats, and wildlife and human nonpoint sources;
- tidal flushing is the main mechanism for removing bacteria from harbor;
- FC concentrations are relatively constant during dry weather; and,
- bacteria is added to harbor at a rate about equal to its removal by tidal flushing." (EPA 2003, 8).

This study recommends utilizing such a model to predict the impacts of stormwater on Cains Brook and Mill Creek (and not solely to the Harbor), a process that could be guided by available GIS data on the UNH GRANIT website (http://www.granit.unh.edu), previously-developed hydrologic budgets available through NH DES and UNH, as well as location-specific MST and VRAP data and WWTF effluent release information required by the Shellfish Program MOU. These models should account for human as well as animal fecal inputs, although it will prove more difficult to measure and predict non-human sources. Periodic observation of wildlife on or around the Brook could be accomplished during annual VRAP sampling, but should also be conducted during autumn months when spikes in bacteria have been known to occur, likely from increased bird inputs during migrations (3 pers. comm. 5/4/09). Such modeling efforts must incorporate the variability of both untreated runoff and BMP effluent, and also be closely linked to actual monitoring data (Clary *et al.* 2008), such as the data acquired by VRAP.

iv. Consider Alternatives to Retention/Detention Ponds

Retention ponds have been shown to be effective at reducing bacteria levels in some areas of the country, but are generally ineffective in urban areas, and tend to attract wildlife and waterfowl that can increase bacteria (Clary *et al.* 2008). Swales and detention basins, similarly, appear to have a relatively low degree of effectiveness in reducing bacteria levels, and can even export bacteria (Clary *et al.* 2008). Biofiltration, on the other hand, is a category of stormwater BMPs (including rain gardens and bioretention cells) that shows promise in reducing bacteria, but regular maintenance is essential to their proper functioning (Clary *et al.* 2008). Replacement of the basins currently in use with more effective BMPs might require a substantial initial investment, but the long-term gains achieved in water quality could be significant.

All in all, further monitoring to ensure the proper management of these ponds is essential, especially given increasing development pressures that may result in increased stormwater inputs. The various stormwater basins in use by commercial retailers and large public facilities throughout the watershed may not be being managed as responsibly as they should, as evidenced by the presence of the portable toilet in Kohl's detention pond (Figure 4.6-3) and the presence of trash in several of the basins. In addition to observing the adequacy of management, it would likely prove valuable to study of the types of contaminants that are entering the ponds, since only a comparison of the concentrations and flow of contaminants prior to entering and after exiting them would shed light on their efficacy. Cooperative monitoring efforts (both in the form of periodic bacterial sampling and site visits to observe gross infractions like abandoned portable toilets) between VRAP, SCC, DPW and managers of the retail stores may be the best method to successfully ensure the proper management of the detention basins. This type of effort would benefit from the development of an MOU stating specific duties and a reporting structure among the involved parties.

v. Monitor for Other Microbial Pathogens

As Seabrook continues to work to make improvements in the water quality and ecological character of the Cains Brook watershed, people will likely begin to utilize it more for fishing and the other recreational opportunities it offers. For example, once Cains Pond is dredged, it will be likely to attract fishers and boaters (3 pers. comm. 12/13/07). Such practices will increase the potential for exposure not only to fecal bacteria, but to other microbial pathogens as well. This study suggests that it may be valuable to conduct periodic testing for other potential pathogens, including protozoans like *Cryptosporidium*, and viruses. Because there are no standards set for these organisms, the information would serve only as additional information about the presence of actual pathogens, which would help to inform all interested parties about the public health significance of elevated levels of the various indicator bacteria.

VRAP may be able to provide the resources and people necessary to conduct additional sampling, and would benefit from testing for these microbes at the same locations as current annual sampling sites to develop a baseline pathogen inventory. The results of such an assessment could be incorporated into the next revision of the Cains Brook Management Plan and appropriate measures to reduce these source could be taken.

vi. Conduct Site Analysis of Salisbury Portion of Watershed

The portion of the Cains Brook watershed that lies in Salisbury is not well categorized and/or monitored by Seabrook officials (3 pers. comm. 12/13/07) and the communication between Salisbury and Seabrook is poor regarding the portion of the Cains Brook watershed within Salisbury. Much of this area is not serviced by municipal sewer (although it does have municipal water) according to the Cains Brook Management Plan, which also states that "it would appear that the potentially biggest threat to Cains Brook would be from improperly functioning septic systems [in Salisbury]" (2006, p. 36). Further investigation into the quality of on-site septic systems and subsurface flow of bacteria could be incorporated into a GIS that would likely prove very useful to the restoration; such an activity could be accomplished as a part of the ongoing sewer and water main improvement project in Salisbury. This mapping study would allow Seabrook and NH state departments to work collaboratively with Salisbury officials and residents to jointly eliminate bacteria sources (especially under the guidance of an MOU or interstate commission, as mentioned above). It would be unlikely, however, that funding for this type of site survey would be available directly through NH DES since surveying would occur across state lines, but discretionary funds available through the SCC or contract funds from the sewer project through the Salisbury Department of Public Works might be sufficient. Further assistance could be sought from the EPA Region I office or Massachusetts Department of Environmental Protection, who may have the ability to mandate such an analysis if the need can be adequately shown.

viii. Distinguish Cains Brook Inputs from Others

One of the most critical hurdles that Seabrook may have to overcome is the recognition that Mill Creek and Hampton Harbor are not meeting TMDL standards because of bacteria inputs from Cains Brook. It is interesting to note that the observed percentage of human-borne fecal bacteria was 11% higher in Hampton Harbor than in the Cains Brook watershed (Jones & Landry 2003; Jones, Landry & Edwards 2005), although no clear reasons have been put forward to explain this difference. With potential pathogenic microbial sources in existence in Hampton Harbor, further testing of the hydrology of the Harbor and Mill Creek are vital to help determine whether it is truly Cains Brook that is the source of shellfish bed closures downstream. Dye tracking studies have recently been conducted by NH DES and EPA on the Little River, which is another source of contaminants in the Atlantic Ocean north of Hampton Harbor (Haberman 2009). Dye testing has been performed in the Harbor, but not in recent history, and perhaps not to a sufficient extent (3 pers. comm. 12/13/07). Study participants have suggested that further dye testing is an appropriate next step to determine the sources of bacteria that are transported in the Harbor's currents. In addition, WWTF outfalls and overflows that release effluent into the Harbor should be further studied and the results made publicly available. This process would involve examining aging wastewater pipes, the chemical and biological makeup of wastewater itself, and the quality of management at WWTFs; since WWTF overflows are monitored and reported according to the MOU with the NH Shellfish Program, the frequency and extent of WWTF overflows would be critical to this evaluation. Engineer consultants and the DPW might be best situated to conduct such inspections because their familiarity with these systems is already high.

8. Study Impacts of Bacterial Contamination on Local Economy

There has not, to date, been any thorough examination of the impacts that closed shellfish beds, reduced recreation opportunities and decreased stream and pond extent have had on the economy of Seabrook. Much better known, however, is the influence of development, because of its tangible economic tie-ins. This study revealed that there have been few linkages, aside from anecdotal ones, that relate the negative effects of bacterial pollution to the potential loss of jobs, changes in the type and availability of recreation opportunities, or the extent to which tourism is effected. This study suggests completing such a study as part of the Cains Brook Management Plan Implementation Plan because it would provide the restoration, and more importantly, Seabrook citizens, with concrete evidence that might serve to enhance participation in restoration activities and adoption of bacterial pollution BMPs. This type of study could be led by restoration members with the assistance from outside parties like the NH Coastal Program and NH Sea Grant.

9. Increase Enforcement of Littering Laws

Littering is an omnipresent concern in Seabrook, as several study participants indicated. Contaminated trash can increase bacterial contamination, especially when it contains unprocessed human and pet wastes. It can also provide a steady source of nutrients that augment bacterial growth. Some efforts have been made by local citizens and business owners to clean up the trash, but there is less of a focus on litter *prevention*. Signage to discourage littering is present throughout the watershed in the form of catch basin stenciling and metallic "no-dumping" discs, and notices of fines for littering in places like the I-95 rest stop and in commercial retail parking lots. In addition, littering practices are discouraged in the stormwater management and pet waste pickup brochures, but the effects that these outreach material have had on littering is unclear. Seabrook's littering law enforcement capabilities may be insufficient to handle the broad scale of the problem. In order to identify and stop litterers, it may prove beneficial to develop a coordinated strategy among business owners and road/highway managers and local police. Seabrook police have been made aware of the extent of the littering problem (3 pers. comm. 2/11/09), but would be better able to enforce littering laws if an organized and tested reporting system were in place. Enforcement of littering laws should focus on some of the most severely affected areas, including the Route 1 Corridor and I-95 Rest Stop (1 pers. comm. 11/30/07).

10. Use of Biofilms and Other Filtration BMPs:

Various types of filters are increasingly being used in the treatment of contaminated stormwater (Urbonas n.d.). Such filters can act on stormwater via physical trapping of sediment and floatable material, or cause chemical or biological changes in the character of stormwater. Sand filters have been used for approximately 100 years to treat stormwater and are well-tested (Urbonas n.d.). There are numerous types of sand filters, including slow, rapid and re-circulating. The design of these systems requires attention to flow-through rates as a function of cost and maintenance needs, because high volumes of stormwater input can decrease a sand filter's functionality.

Biofilms are a type of biological filter in which microorganisms adhere to and proliferate on an inert surface, removing organic compounds and even killing other bacteria. Biofilms have been successfully used in WWTFs and have been installed in stormwater infrastructure to a lesser extent. Juniper fiber and sphagnum moss, which have up to 400 to 7,000 times as much surface area as sand filters, respectively, are being explored for use in stormwater infrastructure (Byrd *et al.* 2001). These filters not only filter out small particles, but also provide a medium for the growth of biofilms. This type of filter would have to be tested for resistance to chlorides and heavy stormwater flow (1 pers. comm. 5/22/09), which could be conducted by the UNH Stormwater Center.

11. Evaluate Restoration Progress Systematically

In light of the progress made to restore the Cains Brook watershed and open up shellfishing in Mill Creek and other parts of Hampton Harbor, past and future efforts must be tracked and monitored in a systematic way so that successes can be clearly and appropriately demonstrated, and setbacks targeted and remediated. The Watershed Action Plan and Implementation Plan are both useful in this regard, but they do not lay out any specific intelligence-gathering protocol, reporting structure or methods to measure success. Restoration participants might benefit from a one- or two-day workshop to institute criteria that would help to evaluate progress. Facilitation of this kind of workshop could be provided by local extension networks that have demonstrated expertise in these areas. A process similar to the policy process as outlined in Clark (2002) would provide the means to accurately specify the problem and develop alternative solutions, as well as measure progress towards restoration goals.

E. Closing Remarks

This study examined the extent to which the Cains Brook watershed restoration is moving in the right direction towards reducing the threat of potentially pathogenic bacteria in it surface waters. By interviewing and surveying participants involved in the restoration, as well as reviewing relevant literature and technical reports, it appears that progress is being made in the right direction, albeit slowly. The restoration process has incorporated the needs and opinions of many groups both within Seabrook and also the larger New Hampshire community. Future steps must involve augmenting monitoring efforts both within and outside the watershed and coordinating with neighboring town to eliminate possible external bacterial pollution sources. Seabrook also needs to enhance education efforts within its border so that the problem of pathogenic microbial pollution is accurately specific and misperceptions are eliminated. A better understanding of the hydrology of Cains Brook, Mill Creek and the Hampton Harbor will serve to pinpoint more accurately the sources of bacteria that are present. The future for a healthy Cains Brook seems encouraging, despite continuing development pressures, because there are a committed core of people working hard to identify and eliminate bacteria through a wide variety of management initiatives. Residents and tourists alike may soon, as in times past, be able to enjoy clamming, boating and other recreational activities there under a minimal public health threat from pathogens.

Ode to Cains Brook

Sitting in a shady nook,
Down by a little babbling brook,
With a fish pole 'tween my knees,
Just doing anything I please.
Who could ask for something more,

Than to catch fish by the score.
Watch the water slowly pass,
Think I caught another bass.
In the shade of a pine bough,
That is where you'll find me now.
Ask me what I want in life?
Surely this care and strife.
If the Lord could hear my plea,
Would but lend an ear to me.
I am sure he'd grant my wish.
All I want is just to fish.
Heaven must be just like this,
For us men who like to fish.

John R. Foote, 1944

LIST OF REFERENCES

Arnold, C. & C.J. Gibbons (1996). Impervious Surface coverage The Emergence Environmental of a Key Indicator. Journal of the American Planning Association, Vol. 62, No. 2, pp. 243 - 258.

Beran, G.W. (1994). Handbook of Zoonoses: Section B. Viral. 2nd Edition, CRC Press.

Brezonik, P. & T. Stadelmann (2002). Analysis and predictive models of stormwater runoff volumes, loads, and pollutant concentrations from watersheds in the Twin Cities metropolitan area, Minnesota, USA. Water Research: Vol. 36, No. 7, pp. 1743-1757.

Burton, G.A. Jr., D. Gunnison & G.R. Lanza (1987). Survival of Pathogenic Bacteria in Various Freshwater Sediments. Applied and Environmental Microbiology: Vol. 53, No. 4, pp. 633-638.

Byrd, V.L., D.J. Reinemann, J.A. Malison, J. Hansen, M.E. Raabe, & J. Han (2001). Demonstration of the Use of Natural Fiber Filters and Airlift Pumps in Recirculation. Written for presentation at the 2001 ASAE Annual International Meeting. Accessed 6/05/09 at: www.fpl.fs.fed.us/documnts/pdf2001/byrd01a.pdf.

Cains Brook and Mill Creek Watershed Management Plan (2006). New Hampshire Estuaries Project. Accessed 6/23/09 at: http://nhep.unh.edu/resources/ pdf/cains_brook_and-tos-06.pdf

Chase, V.P., L.S. Deming & F. Latawiec (1995). Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire. Accessed 8/10/09 online at: http://extension.unh.edu/commdev/Buffers.pdf

Chiaramida, A. (2008a). Town to draft rules for windmill use. Newburyport News: The Daily News Online, Published: December 04, 2008. Accessed 6/22/09 at: http://www.newburyportnews.com/punews/local_story_339233326.html

Chiaramida, A. (2008b). Salisbury selectmen accept $3.9M bid for water, sewer work. Newburyport News: The Daily News Online, Published: February 27, 2008. Accessed 8/1409 at: http://www.newburyportnews.com/punews/ local_story_058072637.html

Clark, T. (2002). The Policy Process: A Practical Guide for Natural Resource Professionals. Yale University Press: New Haven.

Clark, T., A. Willard & C. Cromley (2000). Foundations of Natural Resource Policy and Management. Yale University Press; New Haven and London.

Clary, J., J.E. Jones, B.R. Urbonas, M.M. Quigley, E. Strecker & T. Wagner (2008). Can Stormwater BMPs Remove Bacteria? The Journal of Surface Water Quality Professionals, May 2008. Accessed 8/5/09 online at: http://www.stormh2o.com/may-2008/bacterial-research-bmps.aspx

Conway, T.M. & R.G. Lathrop 2005. Alternative land use regulations and environmental impacts: assessing future land use in an urbanizing watershed. Landscape and Urban Planning, Vol. 7, No. 1, pp. 1-15.

DeGraaf, R.M. & M. Yamasaki (2000). New England Wildlife: Habitat, Natural History and Distribution. University Press of New England.

de la Crétaz, A.L. & P.K. Barten (2007). Land use effects on streamflow and water quality in the northeastern United States. CRC Press; University of Massachusetts, Amherst.

Entry, J.A., Robert K. Hubbard, Janice E. Thies, and Jeffry J. Fuhrmann (2000). The Influence of Vegetation in Riparian Filterstrips on Coliform Bacteria: I. Movement and Survival in Water. Journal of Environmental Quality: Vol. 29, No. 4, pp. 1206-1214.

U.S. Food and Drug Administration (FDA)

2007 Guide for the Control of Molluscan Shellfish 2007 Revision. Accessed 7/31/09 at: http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FederalStatePrograms/NationalShellfishSanitationProgram/ucm046353.htm

Feng, P., S.D. Weagant, & M.A. Grant (2002). BAM: Enumeration of Escherichia coli and the Coliform Bacteria. US FDA Bacteriological Analytical Manual, 8th Edition, Chapter 4. Accessed online 6/24/09 at: http://www.fda.gov/Food/Science Research/LaboratoryMethods/BacteriologicalAnalyticalManualBAM/ucm064948.htm

Fleming, P. (2004). EPA Settles Enforcement Case with Seabrook, NH for Clean Water Act Violations. Release date: 07/15/04. EPA Press Office: Release #04-07-12. Accessed 6/17/09 at: http://yosemite.epa.gov/opa/a1press.n3/6427a6b7538955c585257359003f0230/8f90db86049f34ec852570dc006ca453!OpenDocument.

Griffith, J.G., S.B. Weisberg & C.D. McGee (2003). Evaluation of microbial source tracking methods using mixed fecal sources in aqueous test samples Journal of Water and Health: Vol. 1, No. 4: pp. 141-151.

Gagliardi, J.V. & J.S. Karns (2000). Leaching of Escherichia coli O157:H7 in Diverse Soils under Various Agricultural Management Practices. Applied and Environmental Microbiology, Vol. 66, No. 3, pp. 877-883.

Geldreich, E.E. (1996). Pathogenic Agents in Freshwater Resources. Hydrological Processes, Vol. 10, pp. 315-333.

Gorenstein, D. (2009). Recession Hits Seabrook Hard. New Hampshire Public Radio Online. Accessed 8/4/09 at: http://www.nhpr.org/node/24083.

Grumbine, R.E. (1994). What is ecosystem management? Conservation Biology: No. 8, pp. 27-38.

Governor and Executive Council Minutes, June 13, 2007. State House, Concord, New Hampshire. Accessed 6/17/09 at: http://www.sos.nh.gov/G&C/G&CMinutes6-13-07.htm

Haberman, S. (2009). Ocean runs red off Little Boar's Head. Seacoastonline.com. Accessed 6/22/09 at: http://www.seacoastonline.com/articles/20090519-NEWS-90519032.

Hagerdorn, C., S. Robinson, J. Filtz, S. Grubbs, T. Angier, & R. Reneau Jr. (1999). Determining Sources of Fecal Pollution in a Rural Virginia Watershed with Antibiotic Resistance Patterns in Fecal Streptococci. Applied and Environmental Microbiology: Vol. 65, No. 12, pp. 5522–5531.

Hampson, P.S., Treece, M.W. Jr., Johnson, G.C., Ahlstedt, S.A., & Connell, J.F. (2000). Water Quality in the Upper Tennessee River Basin, Tennessee, North Carolina, Virginia, and Georgia 1994–98: U.S. Geological Survey Circular 1205, 32 p., on-line at http://pubs.water.usgs.gov/circ1205.

Howell, J.M., M. S. Coyne & P. L. Cornelius (1996). Effect of Sediment Particle Size and Temperature on Fecal Bacteria Mortality Rates and the Fecal Coliform/Fecal Streptococci Ratio. The Journal of Environmental Quality: Vol. 25, pp. 1216-1220.

Jick, T.D. (1979). Mixing Qualitative and Quantitative Methods: Triangulation in Action. A1inistrative Science Quarterly, Vol. 24, No. 4, pp. 602-611.

Jones, S.H. (1997). Impact of Septic Tank Disconnection on Water Quality in Coastal Surface Water and Subsurface Environments. Final Report. New Hampshire Office of State Planning, New Hampshire Coastal Program, Concord, NH. Grant Award # NA 67OZ0221. NOAA, Washington, DC. 90 pp.

Jones, S.H. (1998). Bacterial and Nutrient Dynamics in Stormwater Control Systems in New Hampshire. Final Report to the U.S. Geological Survey.

Jones, S.H. (2001). A Technical Characterization of Estuarine and Coastal New Hampshire. The New Hampshire Estuaries Project, Portsmouth, NH.

Jones, S.H. & N. Landry (2003). Tracking Bacterial Pollution Sources in Hampton Harbor. A final report to the United States Environmental Protection Agency and the New Hampshire Estuaries Project/Office of State Planning. University of New Hampshire, Jackson Estuarine Laboratory, Durham, NH and New Hampshire Department Of Environmental Services, Water Division, Watershed Management Bureau, Concord, NH. April 2003.

Jones, S.H, N. Landry, & C. Edwards (2005). Tracking Bacterial Pollution Sources in the Cains Brook and Mill Creek Watersheds. A final report submitted to the US EPA, December 2005.

Jones, S.H. & R. Langan (1996). Assessment of the Effectiveness of Permanent Stormwater Control Measures. Final Report: NOAA Grant Award #NA47OZ0320. NH Office of State Planning, NH Coastal Program Concord, NH.

Jones, S.H., S. Sumner, N. Landry & J. Connor (2004). Pollution Source Tracking at New Hampshire (USA) Beaches. NH Department of Environmental Services, Concord, NH. Accessed 8/1/09 online at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/pollution_source_tracking.pdf.

Lee, J.H., K.W. Bang, L.H. Ketchum, Jr., J.S. Choe and M.J. Yu (2002). First flush analysis of urban storm runoff. The Science of The Total Environment. Vol. 293, No.s 1-3, pp. 163-175.

Lakes Management Advisory Committee and the Rivers Management Advisory Committee 1998. The Sustainability Of New Hampshire's Surface Waters. Accessed 8/8/09 online at: http://www.nh.gov/des/organization/divisions/water/wmb/lakes/documents/sustainability_initiative.pdf.

Long, T. (2009). Seacoast Communities Remain Optimistic as Economy Flags. The Boston Globe. Accessed 6/17/09 at: http://www.boston.com/news/local/articles/2009/05/03/seacoast_communities_remain_optimistic_as_economy_flags

Mallin, M.A., K.E. Williams, E.C. Esham, & R.P. Lowe (2000). Effect Of Human Development On Bacteriological Water Quality In Coastal Watersheds. Ecological Applications: Vol. 10, No. 4, pp. 1047-1056.

Mallin, M.A., S.H. Ensign, M.R. McIver, G.C. Shank, & P.K. Fowler (2001). Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. Hydrobiologia: No. 460, pp. 185-193.

Meays, C.L., K. Broersmab, R. Nordina, & A. Mazumdera (2004). Source Tracking Fecal Bacteria In Water: A Critical Review Of Current Methods. Journal of Environmental Management: Vol. 73, No. 1, pp. 71-79.

Morse, S. (2009). Saving the Cains Brook Watershed – Commercial fees to help restore resource for kayakers and others. *Seacoast Sunday*: January 4, 2009. Accessed 6/17/09 at: http://www.seacoastonline.com/articles/20090104-NEWS-901040328.

Nelson, M., S.H. Jones, C. Edwards & J.C. Ellis (2008). Characterization of *Escherichia coli* populations from gulls, landfill trash, and wastewater using ribotyping. Diseases of Aquatic Organisms, Col. 81, pp. 53-63.

New Hampshire Department of Environmental Services (NH DES).

1999 New Hampshire Nonpoint Source Management Plan. NH DES-WD-99-7. NH Department of Environmental Services, Concord, NH.

2001 Bacteria in Surface Waters. NH DES-BB-14. NH Department of Environmental Services, Concord, NH.

2004a Best Management Practices to control nonpoint source pollution: A guide for Citizens and town officials. NH DES-WD-03-42. NH Department of Environmental Services, Concord, NH.

2004b Total Maximum Daily Load (TMDL) Study for Bacteria in Hampton/Seabrook Harbor. NH Department of Environmental Services, Concord, NH. Accessed 6/25/09 at: www.epa.gov/waters/tmdldocs/10014_final_hampton_harbor.pdf.

2006 Guidelines and Standard Operating Procedures: IDDE and Pollution Prevention/ Good Housekeeping for Stormwater Phase II Communities in New Hampshire. NH Department of Environmental Services, Concord, NH.

2007a Nonpoint Source Management Annual Report 2006. R-WD-07-32. NH Department of Environmental Services, Concord, NH.

2007b Seabrook Town Beach, Seabrook Beach Water Quality Report Summer 2006. NH Department of Environmental Services, Concord, NH. Accessed 6/20/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2006seabrook_tb.pdf

2007c Seabrook Harbor Beach, Seabrook, Beach Water Quality Report Summer 2006. Prepared by: E. Bouthiette & S. Sumner. NH Department of Environmental Services, Concord, NH. Accessed 7/29/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2006seabrook_harbor.pdf

2008a Causes of Bacteria in Water Samples. NH DES-WD-DWGB-4-2. NH Department of Environmental Services, Concord, NH.

2008b Interpreting the Presence of Coliform Bacteria in Drinking Water. NH DES-WD-DWGB-4-1. NH Department of Environmental Services, Concord, NH.

2008c Seabrook Town Beach, Seabrook Beach Water Quality Report Summer 2007. Prepared by: C. Merrifield & A. Carlson. NH Department of Environmental Services, Concord, NH. Accessed 6/20/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2007seabrook_tb.pdf

2008d Seabrook Harbor Beach, Seabrook, Beach Water Quality Report Summer 2006. Prepared by: C. Merrifield & A. Carlson. NH Department of Environmental Services, Concord, NH. Accessed 7/29/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2007seabrook_harbor.pdf

2008e Seabrook Water Department Compliance Report. NH Department of Environmental Services, Concord, NH. Accessed 6/20/09 at: http://www2.des.state.nh.us/OneStop/DWPB.aspx

2008f New Hampshire Section 305(b) and 303(d) Surface Water Quality Report 2008. Prepared by: G. Comstock, P.E. & K. Edwardson NH DES Watershed Management Bureau. NH Department of Environmental Services, Concord, NH. Accessed 6/20/09 at: des.nh.gov/organization/divisions/water/wmb/swqa/2008/

2009a Nonpoint Source Management Annual Report 2008. R-WD-09-7. NH Department of Environmental Services, Concord, NH.

2009b Seabrook Town Beach, Seabrook Beach Water Quality Report Summer 2008. NH Department of Environmental Services, Concord, NH. Accessed 6/20/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2008seabrook_tb.pdf

2009c Hampton Harbor Beach, Hampton, Beach Water Quality Report Summer 2008. Prepared by: Carolyn Merrifield, Jessica Devoid, Teresa Ptak, Sonya Carlson & Jody Connor. NH Department of Environmental Services, Concord, NH. Accessed 7/29/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2008hampton_harbor.pdf

2009d Seabrook Harbor Beach, Seabrook, Beach Water Quality Report Summer 2008. Prepared by: C. Merrifield, J. Devoid, T. Ptak, S. Carlson & J. Connor. NH Department of Environmental Services, Concord, NH. Accessed 7/29/09 at: http://des.nh.gov/organization/divisions/water/wmb/beaches/beach_reports/documents/2008seabrook_harbor.pdf

New Hampshire Economic & Labor Market Information Bureau (2008). Seabrook, NH Census Data, NH Employment Security. Accessed 6/23/09 at: http://www.nh.gov/nhes/elmi/htmlprofiles/seabrook.html

New Hampshire Estuaries Project (NHEP) (or Piscataqua Region Estuaries Partnership).

2006a New Hampshire Estuaries Project State of the Estuaries Report. Accessed 6/12/09 at: www.nhep.unh.edu/resources/pdf/2006_state_of_the-nhep-06.pdf

2006b Environmental Indicator Report: Land Use and Development, University of New Hampshire , Durham, NH. May 2006. Accessed 6/26/09 at: http://www.nhep.unh.edu/resources/pdf/env_ind_land_use-nhep-06.pdf.

2008 Shellfish Spotlight. Accessed 7/31/09 at: http://www.nhep.unh.edu/resources/pdf/shellfish_spotlight-nhep-08.pdf

2009 Environmental Indicators Report. Prepared by P. Trowbridge, June 2009, under a grant by the U.S EPA National Estuary Program. Accessed 8/3/09 online at: http://www.nhep.unh.edu/resources/pdf/environmental_indicators_report=prep-09.pdf.

New Hampshire Volunteer River Assessment Program (VRAP).

2009 Cains Brook Watershed Water Quality Report (February 2009). Prepared by: T. Walsh, J. Drociak, D. Mucciarone, C. Foley. Accessed 6/1/09 at: http://des.nh.gov /organization/divisions/water/wmb/vrap/cains/documents/data_report2008.pdf

2008 Cains Brook Watershed Water Quality Report (February 2008). Prepared by: Ted Walsh, J. Drociak, C. Martin. Accessed 6/1/09 at: http://des.nh.gov/organization/ divisions/water/wmb/vrap/cains/documents/data_report2007.pdf

Noble, R.T., S.M. Allen, A.D. Blackwood, W. Chu, S.C. Jiang, G.L. Lovelace, M.D. Sobsey, J.R. Stewart & D.A. Wait (2003). Use of viral pathogens and indicators to differentiate between human and non-human fecal contamination in a microbial source tracking comparison study. Journal of Water and Health: Vol. 1, No. 4: pp. 195-207.

Paul, M.J & J.L. Meyer (2001). Streams in the Urban Landscape. Annual review of Ecological Systems: Vol. 33, pp. 333-365.

Peterson, J., A. Stone & J. Houle (n.d.). Protecting Water Resources and Managing Stormwater: A Bird's Eye View for New Hampshire Communities. Accessed 8/3/09 online at: http://www.unh.edu/erg/cstev/pubs_specs_info/ stormwater_guide.pdf

Radasci, S. (1996). Assessment of Potential Nonpoint Sources of Pollution from the Great Brook Watershed to the Exeter Watershed: A Policy Implementation Audit. Thesis, UNH.

Rose, J.B., P.R. Epstein, E.K. Lipp, B.H. Sherman, S.M. Bernard, & J.A. Patz (2001). Climate Variability and Change in the United States: Potential Impacts on Water- and Foodborne Diseases Caused by Microbiologic Agents. Environmental Health Perspectives: Vol. 109, No. 2, pp. 211-220.

Rosen, B. (2000). Water-borne Pathogens in Agricultural Watersheds. WSSI — Technical Note, 2 February 2000. Report to the USDA.

Routio, P. (2007, unpublished). Sampling. Accessed 7/28/09 at: http://www2.uiah.fi/projects/metodi/152.htm.

Santo Domingo, J.S., Edge, T., Griffith, J., Hansel, J., Harwood, V.J., Jenkins, M., Layton, A., Marirosa, M., Nakatsu, C., Oshiro, R., Sadowsky, M., Shanks, O., Stelma, G., Stewart, J., Stoeckel, D., Wiggins, B., & Wilbur, J. (2005). Microbial source tracking guide document. US Environmental Protection Agency Special Publication EPA/600R-05/064.

Schillinger, J.E. & J.J. Gannon (1985). Bacterial adsorption and suspended particles in urban stormwater. Journal of the Water Pollution Control Federation: Vol. 57, No. 5: pp. 384-389.

Scott, T.M., J.B. Rose, T.M. Jenkins, S.R. Farrah & J. Lukasik (2002). Microbial Source Tracking: Current Methodology and Future Directions. Applied and Environmental Microbiology, Vol. 68, No. 12: pp. 5796-5803,

Seabrook Conservation Commission (n.d.). Fact Sheet on Wetland Buffers. Accessed 8/10/09 online at: http://www.seabrooknh.org/Con comm/Wetland buffers.pdf.

Shelton, D.R., YA. Pachepsky, A.M. Sadeghib, W.L. Stoutc, J.S. Karnsa & W.J. Gburek. Release Rates of Manure-Borne Coliform Bacteria from Data on Leaching through Stony Soil. Vadose Zone Journal, Vol. 2, pp. 34-39.

Tartera, C., & J. Jofre (1987). Bacteriophages active against Bacteroides fragilis in sewage-polluted waters. Applied Environmental Microbiology, Vol. 53, pp. 1632-1637.

Taylor, S. J., & R. Bogdan (1998). Introduction to Qualitative Methods: A Guidebook and Resource. 3rd Ed. John Wiley & Sons, Inc.: New York.

Teplitski, M. (2006). *E. coli* and salmonella on animal farms: sources, survival and management. SL-239 Fact Sheet of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Accessed 6/20/09 at: http://edis.ifas.ufl.edu/SS458.

U.S. Environmental Protection Agency (EPA)

2003 EPA New England's TMDL Review: Hampton/Seabrook Harbor, New Hampshire. Accessed 7/31/09 at: www.epa.gov/NE/eco/tmdl/assets/pdfs/nh/hamptonseabrookharbor.pdf

2008 NPDES Phase II Small MS4 General Permit Town of Seabrook Annual Report: May 1, 2008. Accessed 6/17/09 at: http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/nh/reports/2008/Seabrooknh08.pdf.

Urbonas, B.R. (n.d.). Stormwater Sand Filter Sizing and Design: A Unit Operations Approach. Accessed 6/1/09 at: www.udfcd.org/downloads/pdf/tech_papers/Sand-flt-paper.pdf.

Walker, S.E., S. Mostaghimi, T.a. Dillaha, F.E Woeste (1990). Impacts on bacteria levels in runoff from agricultural lands. Transactions of the ASAE, Vol. 33, No. 3: pp. 807-817.

Walsh, P.J. (2008). Oceans and human health: risks and remedies from the seas. Academic Press: Burlington, MA; San Diego, CA; London.

Yin, R.K. (1994). Case Study Research: Design and Methods 2nd Ed. Sage Publications, London, New Delhi.

Young, K.D. & E.L. Thackston (1999). Housing Density And Bacterial Loading In Urban Streams. Journal Of Environmental Engineering, Vol. 125, No. 12, pp. 1177-1180.

APPENDICES

APPENDIX I

FOCUSED INTERVIEW QUESTIONNAIRE

I. Problem Orientation

1. Are you familiar with the Cains Brook and Mill Creek Watershed Restoration Project in Seabrook?
    a. (If yes,) have you had any personal role in the Restoration?
    b. (If no,) give them background on the Project and offer to provide Executive summary of Project at the end of the interview)

2. Why do you think the Town of Seabrook is trying to restore the Cains Brook Watershed?

3. Are you personally aware of any water quality problems there?
    a. (If yes,) what are they?

4. What about bacterial pollution? Do you feel as though bacteria might currently be a threat to the health of the Cains Brook Watershed?

5. Are you familiar with any studies that have investigated the sources of bacteria in the watershed?
    a. (If no,) SKIP TO QUESTION #6.
    b. (If yes,) do you know if the results of those studies are being incorporated into the efforts of the Restoration, and if so, how?
    c. (If yes,) do you feel that the results of those studies are being used effectively? Why or why not?

6. (If NO to Q5,) So there are various studies that have sought to locate the sources of bacterial pollution, especially fecal bacteria, into Cains Brook and its associated waters.
    a. Do you personally have an idea of what some of the sources – specific land-use activities or locations – of harmful bacterial might be?
    b. What sources or activities do you feel might contribute the most bacteria to the water?

7. Let's discuss ways to minimize bacterial pollution. Are you familiar with any policies or management actions that can aid in minimizing bacterial pollution?
    a. To your knowledge, what policies or management actions to cut down on bacterial pollution are being used in and around the Cains Brook Watershed?
    b. Do you feel that there are any policies or management actions that are ineffective at minimizing bacterial pollution being examined in this case?

III. Social Process:

8. Were you personally involved in creating the Cains Brook/Mill Creek Watershed Management Plan?

   a. (If yes,) in what way?

9. Do you or your organization personally have any responsibilities for the implementation of the Plan?

   a. (If yes,) can you please describe them?

10. Do you feel that there are any individuals or organizations that are not involved in the Restoration that ought to be?

   a. (If yes,) who, and why should they be involved?

   b. Do you feel that the public has been actively engaged in helping to set the direction of the Restoration Project?

11. In your opinion, how well are the activities of the Restoration Project being coordinated?

IV. Decision Process

12. Do you feel that there are any policies or management strategies in the Cains Brook/Mill Creek Watershed Management Plan that target specific sources of bacterial pollution?

   a. (If yes,) which ones do you think are the most important?

13. Do you feel that there are any policies or management actions that might reduce bacterial pollution that have not yet been explored?

14. How clearly and effectively do you believe the Cains Brook/Mill Creek Watershed Management Plan defines or discusses the problem of bacterial pollution?

15. How important is it for policies and management actions to address bacterial pollution based on specific, identified sources of bacteria?

16. Are you aware of any monitoring for bacterial pollution in the watershed?

17. Are you aware of any enforcement actions (such as fines or criminal or civil charges) that have been taken to reduce bacterial pollution?

18. In your opinion, do you feel that the current efforts to reduce bacterial pollution in the watershed will prove to be effective?

   a. Why or why not?

APPENDIX II

LETTER OF INFORMED CONSENT

To the participants in this study:

The purpose of this research is to gain a better understanding of the means through which information on the sources of bacterial pollution is being incorporated into the restoration of the Cains Brook/Mill Creek Watershed. The goals of these interviews are to understand how aware people are of the problem of bacterial pollution, which policies and best management practices are in place and how are they being employed to address these sources. The information collected by this study may serve to assist the restoration project by identifying gaps in policies and/or management strategies that result in a failure to succes3ully address known bacterial pollution sources. Participants in this study include local landowners, Seabrook Town Officials, members of local businesses, members of non-governmental organizations and staff of involved engineering firms.

You are being asked to participate in a focused interview that will last for approximately one hour. There may be additional contact necessary if it will help to further clarify your responses. I will take written notes during the interview but I will also tape-record your responses with your permission. Please feel free to stop the interview at any time. I will also turn off the tape recorder upon request. I will only cite you as a source and quote you by name in my research if you give me your written permission. All of the interview data will be stored in a secure, locked location and destroyed within 5 years. If you have questions about this study and would like to contact me, Aaron Kornbluth, please do so at:

326 Nesmith Hall, Department of Natural Resources
The University of New Hampshire, Durham, NH 03824
Phone: (603) 953-4040 | *Fax*: (603) 862-4976 | *Email*: abk2@unh.edu

You can also contact my advisor, Dr. Mimi Becker (mimi.becker@unh.edu), at the same location. If you have any questions about your rights as a research subject, please contact Julie Simpson in the UNH Office of Sponsored Research at (603) 862-2003 or by email at julie.simpson@unh.edu.

I certify that I have read the above statement and agree to participate as an interviewee under the conditions as stated above. I am aware that I can discontinue participation at any time without penalty.

x____________________________________ ________________
Signature of Participant Date

I agree to the use of an audiotape device under the conditions that I may request that it be turned off at any time during the interview.

x____________________________________ ________________
Signature of Participant Date

APPENDIX III

INSTITUTIONAL REVIEW BOARD APPROVAL TO CONDUCT RESEARCH

University of New Hampshire

Research Conduct and Compliance Services, Office of Sponsored Research
Service Building, 51 College Road, Durham, NH 03824-3585
Fax: 603-862-3564

23-Oct-2007

Kornbluth, Aaron
Natural Resources, James Hall
45 Hough Street
Dover, NH 03820

IRB #: 4104
Study: Tracking Bacterial Pollution in the Cains Brook/Mill Creek Watershed: Implications for Policy and Management
Approval Date: 22-Oct-2007

The Institutional Review Board for the Protection of Human Subjects in Research (IRB) has reviewed and approved the protocol for your study as Exempt as described in Title 45, Code of Federal Regulations (CFR), Part 46, Subsection 101(b) with the following comment(s):

The researcher might not want to destroy the data at the end of the study. Rather, he should destroy recordings once transcribed and then at the end of the study, de-identify remaining data.

Researchers who conduct studies involving human subjects have responsibilities as outlined in the attached document, *Responsibilities of Directors of Research Studies Involving Human Subjects.* (This document is also available at http://www.unh.edu/osr/compliance/irb.html.) Please read this document carefully before commencing your work involving human subjects.

Upon completion of your study, please complete the enclosed pink Exempt Study Final Report form and return it to this office along with a report of your findings.

If you have questions or concerns about your study or this approval, please feel free to contact me at 603-862-2003 or Julie.simpson@unh.edu. Please refer to the IRB # above in all correspondence related to this study. The IRB wishes you success with your research.

For the IRB,

Julie F. Simpson
Manager

cc: File
Becker, Mimi

APPENDIX IV

LIST OF INTERVIEW AND SURVEY PARTICIPANTS, ROLE IN RESTORATION AND DATE OF INTERVIEW/SURVEY

Participant Title	Unique Identifier	Participant's Role in Restoration	Interview/ Survey	Date(s)
Chief Engineer for Waterfront Engineers LLC	1	Lead role in producing the CBMCWMP; responsible for developing and installing bacterial pollution controls and BMPs	Interview	11/30/07
UNH Research Associate Professor/MST Researcher	2	Conducted MST studies in Cains Brook Watershed in 2003 and 2005	Interview	12/12/07
Chair of the Seabrook Conservation Commission	3	Lead role in producing the CBMCWMP; responsible for developing and installing bacterial pollution controls and BMPs; oversees spending of SCC funds	Interview	12/13/07 & 2/11/09
NH DES Watershed Outreach Coordinator	4	Reviewed proposals and selected grants for litter prevention and cleanup outreach and education campaigns	Interview	12/18/07
NH DES Coastal Nonpoint Source Pollution Coordinator	5	Responsible for overseeing implementation of stormwater management infrastructure installations, trash surveys, and other BMPs	Interview	12/20/07
NH DES Watershed Management Bureau VRAP Coordinator	6	Coordinated VRAP testing for bacteria in Cains Brook from 2007-2009	Interview	12/19/07
UNH Research Associate Professor	7	Not involved. Interviewed participant to provide external perspective on restoration process	Interview	3/6/09
Former NH DES Official	8	Performed MST studies; coordinated restoration planning with Seabrook	Survey	5/22/09
Code Enforcement Officer/Health Officer/Planning Board Member/	9	Reviews property/construction activities and setbacks from water bodies	Survey	6/8/09
Former NH DOT Bureau of Highway Maintenance Official	10	Reviewed site construction/ applications; coordinated with SCC on restoration efforts	Survey	6/5/09

APPENDIX V

ONLINE SURVEY QUESTIONNAIRE

1. Consent to Participate

Tracking Bacterial Pollution in the Cains Brook/Mill Creek Watershed: Implications for Policy and Management

Dear Survey Participant:

The purpose of this research is to gain a better understanding of the means through which information on the sources of bacterial pollution is being incorporated into the restoration of the Cains Brook/Mill Creek Watershed in Seabrook, NH and Salisbury, MA. The goals of this survey are to understand how aware people are of the problem of bacterial pollution, which policies and best management practices are in place and how are they being employed to address these sources. The information collected by this study may serve to assist the restoration project by identifying gaps in policies and/or management strategies that result in a failure to successfully address known bacterial pollution sources. Participants in this study include local landowners, Seabrook Town Officials, members of local businesses, members of non-governmental organizations and staff of involved engineering firms.

You are being asked to participate in a survey that will take approximately 20-30 minutes. There may be additional contact necessary if it will help to further clarify your responses. Please feel free to stop the survey at any time. I will not identify you by name or title, but instead use a pseudonym or unique identifier. I will have sole, protected access to your survey responses. All of the survey data will be stored in a secure, locked location and destroyed/deleted within 5 years. If you have questions about this study and would like to contact me, Aaron Kornbluth, please do so at:

326 Nesmith Hall, Department of Natural Resources
The University of New Hampshire
Durham, NH 03824
Phone: (603) 953-4040
Fax: (603) 862-4976
Email: abk2@unh.edu

You can also contact my advisor, Dr. Mimi Becker (mimi.becker@unh.edu), at the same location. If you have any questions about your rights as a research subject, please contact Julie Simpson in the UNH Office of Sponsored Research at (603) 862-2003 or by email at julie.simpson@unh.edu.

By clicking the "Next" button below, you consent to participate in the survey and the use of your input as described above.

Thank you for your time and assistance.

2. Watershed Restoration Project

1. Are you familiar with the Cains Brook/Mill Creek Watershed Restoration Project in Seabrook, NH?

- Yes
- No
- Prefer Not to Answer

2. Have you had any personal role in the restoration of the Cains Brook/Mill Creek Watershed?

- Yes
- No
- Don't Know
- Prefer Not to Answer

If "Yes," please describe your role.

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3. Why do you think the Town of Seabrook is trying to restore the Cains Brook/Mill Creek Watershed?

3. Water Quality Problems

4. Are you personally aware of any water quality problems in the Cains Brook/Mill Creek Watershed in Seabrook, NH?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Prefer Not to Answer

If "Yes," in your judgement, what do you believe are the water quality problems?

5. How concerned are you that bacteria might currently be a threat to the health of the Cains Brook/Mill Creek Watershed?

- ○ 1 - Extremely concerned
- ○ 2 - Somewhat concerned
- ○ 3 - Slightly concerned
- ○ 4 - Not at all concerned
- ○ Prefer Not to Answer

Please elaborate upon your response.

6. To what extent are you familiar with any studies that have investigated sources of bacteria in the watershed?

- ○ 1 - Extremely familiar
- ○ 2 - Somewhat familiar
- ○ 3 - Slightly familiar
- ○ 4 - Not at all familiar
- ○ Prefer Not to Answer

If you are even slightly familiar with any of the studies, please describe the study goal(s) and result(s).

7. To what extent are you aware of whether these studies are being incorporated into the efforts of the Cains Brook/Mill Creek Restoration?

- ◯ 1 - Extremely aware
- ◯ 2 - Somewhat aware
- ◯ 3 - Slightly aware
- ◯ 4 - Not at all aware
- ◯ Prefer Not to Answer

If you are even slightly aware, please share your knowledge about how they are being incorporated.

8. In your opinion, how effectively do you feel that the results of those studies are being used to achieve the goals of the Restoration?

- ◯ 1 - Extremely effective
- ◯ 2 - Somewhat effective
- ◯ 3 - Slightly effective
- ◯ 4 - Not at all effective
- ◯ Prefer Not to Answer

If you feel the study results are being used even slightly effectively, please elaborate on your answer as to how the study(s) are being used

4. Sources of Bacteria

9. To what extent are you aware of specific bacterial input sources, such as land-use activities or locations, in the Cains Brook/Mill Creek Watershed?

- ◯ 1 - Extremely aware
- ◯ 2 - Somewhat aware
- ◯ 3 - Slightly aware
- ◯ 4 - Not at all aware
- ◯ Prefer not to answer

Please provide examples.

10. To what extent would you judge bacterial pollution to be a threat to the health of the Cains Brook/Mill Creek Watershed?

- ◯ 1 - Extremely threatening
- ◯ 2 - Somewhat threatening
- ◯ 3 - Slightly threatening
- ◯ 4 - Not at all threatening
- ◯ Prefer not to answer

Please comment on your response.

11. Please select all of the policies and management actions that are being followed/used in and around the Cains Brook Watershed to limit bacterial pollution.

- ☐ The Clean Water Act
- ☐ The National Pollution Discharge Elimination System (NPDES)
- ☐ The Comprehensive Shoreline Protection Act (NH RSA §483-B)
- ☐ The Town of Seabrook Master Plan
- ☐ The Cains Brook/Mill Creek Watershed Management Plan
- ☐ Public Outreach and Education
- ☐ Public Participation and Involvement
- ☐ Illicit Discharge Detection and Elimination
- ☐ Construction Site Runoff Control
- ☐ Post Construction Runoff Control
- ☐ Training municipal employees
- ☐ Other (please specify)
- ☐ Inspecting/maintaining Stormwater System
- ☐ Labeling outfalls with signs
- ☐ Volunteer cleanups
- ☐ Volunteer monitoring (such as the Volunteer River Assessment Program (VRAP))
- ☐ Improving procedures for municipal equipment/facilities
- ☐ Cleaning Town Roads
- ☐ Minimizing impacts of fertilizers on town property
- ☐ Minimizing impacts of pesticides on town property
- ☐ Minimizing impacts of pets on town property
- ☐ Don't Know
- ☐ Prefer Not to Answer

12. Of the options that you selected above, please identify the ones that you believe are the most effective at reducing bacterial pollution. (Please select no more than 5)

- [ ] The Clean Water Act
- [ ] The National Pollution Discharge Elimination System (NPDES)
- [ ] The Comprehensive Shoreline Protection Act (NHRSA 483-B)
- [ ] The Town of Seabrook Master Plan
- [ ] The Cains Brook/Mill Creek Watershed Management Plan
- [ ] Public Outreach and Education
- [ ] Public Participation and Involvement
- [ ] Illicit Discharge Detection and Elimination
- [ ] Construction Site Runoff Control
- [ ] Post-construction Runoff Control
- [ ] Training municipal employees
- [ ] Other (please specify)
- [ ] Inspecting/maintaining Stormwater System
- [ ] Labeling outfalls with signs
- [ ] Volunteer cleanups
- [ ] Volunteer monitoring (such as the Volunteer River Assessment Program (VRAP))
- [ ] Improving procedures for municipal equipment/facilities
- [ ] Cleaning Town Roads
- [ ] Minimizing impacts of fertilizers on town property
- [ ] Minimizing impacts of pesticides on town property
- [ ] Minimizing impacts of pets on town property
- [ ] Don't Know
- [ ] Prefer Not to Answer

13. Please discuss why you made the above selection(s) in Question 12.

5. Watershed Management Plan

14. Were you personally involved in creating the Cains Brook/Mill Creek Watershed Management Plan?

- ( ) Yes
- ( ) No
- ( ) Prefer not to answer

If "Yes," in what way(s) were you involved?

15. Do you or your organization personally have any responsibilities for the implementation of the Plan?

- ( ) Yes
- ( ) No
- ( ) Don't Know
- ( ) Prefer not to answer

If "Yes," can you please briefly describe the responsibility(s)?

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16. In your judgment, are there specific individuals or organizations not presently involved in the Cains Brook/Mill Creek Restoration that ought to be?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Prefer not to answer

If "Yes," who, and why should they be involved?

17. To what extent are the activities of the Cains Brook/Mill Creek Restoration Project being coordinated to achieve project goals?

- ○ 1 - Extremely well coordinated
- ○ 2 - Somewhat well coordinated
- ○ 3 - Slightly well coordinated
- ○ 4 - Not at all well coordinated
- ○ Don't Know
- ○ Prefer Not to Answer

Please comment on your response.

6. Management Decisions

18. Are you aware of any policies or management actions to reduce bacterial pollution that are not currently being used?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Prefer Not to Answer

If "Yes," please suggest appropriate policy(s) or management action(s).

19. How clearly and effectively do you believe the Cains Brook/Mill Creek Watershed Management Plan defines or discusses the problem of bacterial pollution?

- ○ 1 - Extremely clear and effective
- ○ 2 - Somewhat clear and effective
- ○ 3 - Slightly clear and effective
- ○ 4 - Not at all clear and effective
- ○ Don't Know
- ○ Prefer Not to Answer

Please comment on your response.

7. Bacterial Pollution Management

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20. Are you aware of any monitoring for bacterial pollution violations in the watershed?

- ◯ Yes
- ◯ No
- ◯ Don't Know
- ◯ Prefer Not to Answer

If "Yes," can you please describe the monitoring effort(s).

21. Are you aware of any enforcement actions (such as "Notice of Violation (NOV)" fines or criminal or civil charges) that have been levied against bacterial pollution in the Cains Brook/Mill Creek Watershed?

- ◯ Yes
- ◯ No
- ◯ Don't Know
- ◯ Prefer Not to Answer

If "Yes," please provide examples.

22. To what extent do you feel that the current efforts to reduce/eliminate bacterial pollution in the Cains Brook/Mill Creek Watershed will prove to be effective?

- ◯ 1 - Extremely effective
- ◯ 2 - Somewhat effective
- ◯ 3 - Slightly effective
- ◯ 4 - Not at all effective
- ◯ Don't Know
- ◯ Prefer Not to Answer

Please comment on your response.

Thank you for your participation in this study! Please click "Done" below to submit your responses or "Prev" to review them and make changes as necessary.

If you have further questions, please do not hesitate to contact me at ab42@unh.edu or by phone at (603) 953-4040.

Sincerely,

Aaron Kornbluth

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