An Assessment of Groundwater Vulnerability in the Ossipee Watershed

for the Green Mountain Conservation Group, Effingham, New Hampshire

Mia Akaogi
Ecological Planning
The Rubenstein School of Environment and Natural Resources
University of Vermont

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Executive Summary

Groundwater is an important source of drinking water both globally and within the United States. Due to population growth and development, groundwater has become increasingly susceptible to contamination from human activities on the land surface. Because of the high costs of groundwater remediation, water resource managers have shifted to proactive methods that prevent groundwater contamination. This report presents strategies for prioritizing groundwater protection efforts in the Ossipee Watershed, in east-central New Hampshire.

The Green Mountain Conservation Group has initiated a groundwater protection program by identifying potential contamination sources in the Ossipee Watershed. This inventory was used to rank potential contamination sources based on their relationship to aquifer recharge areas and designated wellhead protection areas for public water systems.

The groundwater vulnerability analysis uses topography to make assumptions about water flow, and the locations of the potential contamination sources to rank areas within the Ossipee Watershed according to levels of pollution risk. To take into account the possibility that runoff from a potential contamination source might pollute a surface water feature, an additional analysis determined the proximity of these sites to streams, rivers, ponds, lakes and wetlands.

The results of the prioritization strategies used in the previous two sections are explored further and four methods of utilizing this information to support groundwater protection efforts are presented. These methods include: focused public outreach and education, best management practice implementation, recommendations for private well owners, and suggestions for monitoring groundwater quality.

The recommendations are summarized in the final section of the report. Detailed tables and the methods used to calculate groundwater vulnerability are found in the appendices.

Acknowledgments

Many thanks to the following:

- ✤ Deane Wang, my adviser, and Donna Rizzo and Jamie Shanley, members of my graduate studies committee, for their guidance and support.
- ✤ Tara Schroeder, Danielle Dugas, Blair Folts, and the many people associated with the Green Mountain Conservation Group who welcomed me and made my work in the Ossipee Watershed possible.
- ✤ Those affiliated with the Source Water Protection Project including the Ossipee Aquifer Steering Committee and residents of the towns of Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth for their insight and dedication to drinking water protection.
- ✤ Pierce Rigrod at New Hampshire Department of Environmental Services for his technical support.
- ✤ George and Marcia Forrest for offering their home and introducing me to the Ossipee Lake area, both its history and people.
- ✤ The United States Department of Agriculture National Needs Fellowship, New England Grassroots Environmental Fund, and the University of Vermont for providing the necessary funding.
- ✤ My fellow classmates in both the Field Naturalist and Ecological Planning programs for their support and inspiration over the last two years.

Mia Akaogi
Spring 2009

How To Use This Report

Who is this report for?

This report is intended for the Green Mountain Conservation Group and residents of the six Ossipee Watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth. Although the recommendations are specific to this regional context, the concepts and approaches used in this report are applicable to many other situations where groundwater protection is a significant concern.

How is this report organized?

This report is broken up into five parts, each of which builds on the previous. The Introduction begins with a general significance of groundwater and proceeds to explain the specifics of this project through a description of the watershed context, sponsor organization, and relevant definitions. Section 1 presents results from the potential contamination source inventory and relates these to the aquifer and public water systems. Section 2 discusses the groundwater vulnerability analysis conducted for the Ossipee Watershed. Section 3 provides considerations and recommendations based on the results from Section 1 and 2. A summary of the recommendations follows and detailed research methods and comprehensive tables are found in the Appendices.

How can this report be used?

This report is intended as a guide for prioritizing groundwater protection efforts in the Ossipee Watershed through an identification of 1) which potential contamination sources should be the focus of public outreach and education initiatives and 2) where groundwater quality monitoring should begin. In addition, the process of identifying potential sources of groundwater pollution can be applied to other watersheds or used by landowners concerned with their personal wells.

INTRODUCTION

This section of the report includes an overview of the importance of groundwater, background information specific to this project, a description of the sponsor organization, and explanations of important terms used in this report.

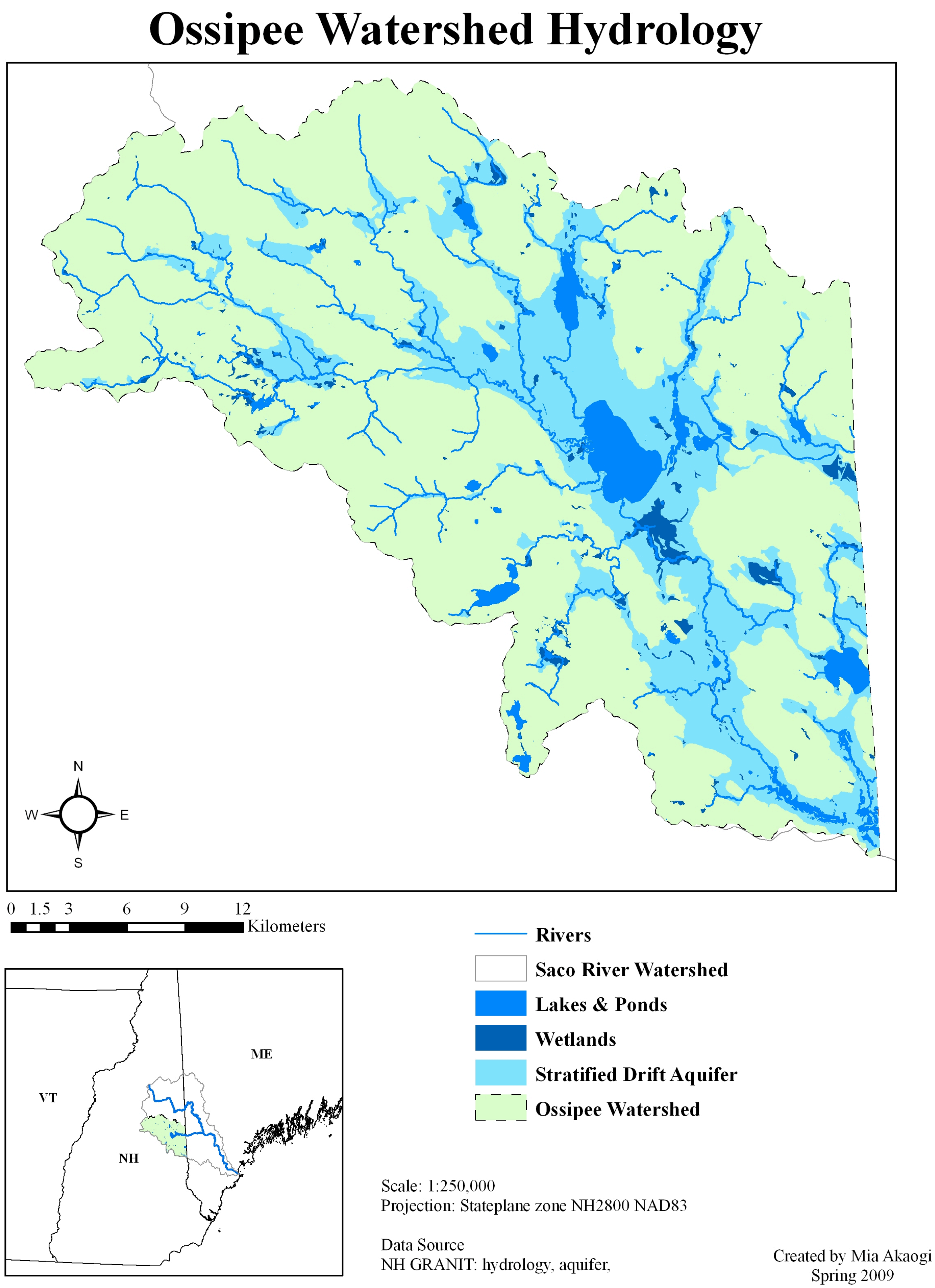
Overview

Hidden below the land surface, groundwater is often overlooked due to its lack of visibility. Groundwater exists below the water table in the saturated zone, where all the spaces between the grains of gravel, sand, silt, clay, and cracks within rocks are completely filled with water (Winter et al. 1998). Within the saturated zone, groundwater flows between and within aquifers. An aquifer is "a geologic formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs" (Reilly et al. 2008). Groundwater is usually found in these subsurface formations, which are often an integral part of the surrounding watershed or basin (National Research Council 1997). Groundwater is widespread, existing virtually everywhere, and therefore aquifers provide a useful spatial boundary for some of the more significant groundwater resources.

As the most important source of fresh water globally and "with an estimated total global withdrawal of 600-700 km3/yr, in one sense groundwater is the world's most extracted raw material" (Foster & Chilton 2003). In addition, as an input for many commodities, groundwater is an integral part of the global economy. It provides 40% of the water demand from industry and 20% of the water used in agriculture (Foster & Chilton 2003). However, perhaps most importantly, groundwater is the source of at least 50% of the world's clean drinking water supply (Foster & Chilton 2003). This dependence on groundwater is especially critical for rural populations. In the United States, groundwater provides 35% of the drinking water supply for urban areas in contrast to at least 95% of the supply for rural areas (US EPA 1990).

In recognition of the importance and necessity of preserving our drinking water supplies, many government agencies and non-profits have increased their focus on groundwater protection. This project aims to fill some of this need in the Ossipee Watershed through a collaboration between the University of Vermont and the Green Mountain Conservation Group.

Funding for this project was provided by the New England Grassroots Environmental Fund and the USDA National Needs Fellowship.



Map 1. Hydrology of the Ossipee Watershed including both surface water and groundwater resources.

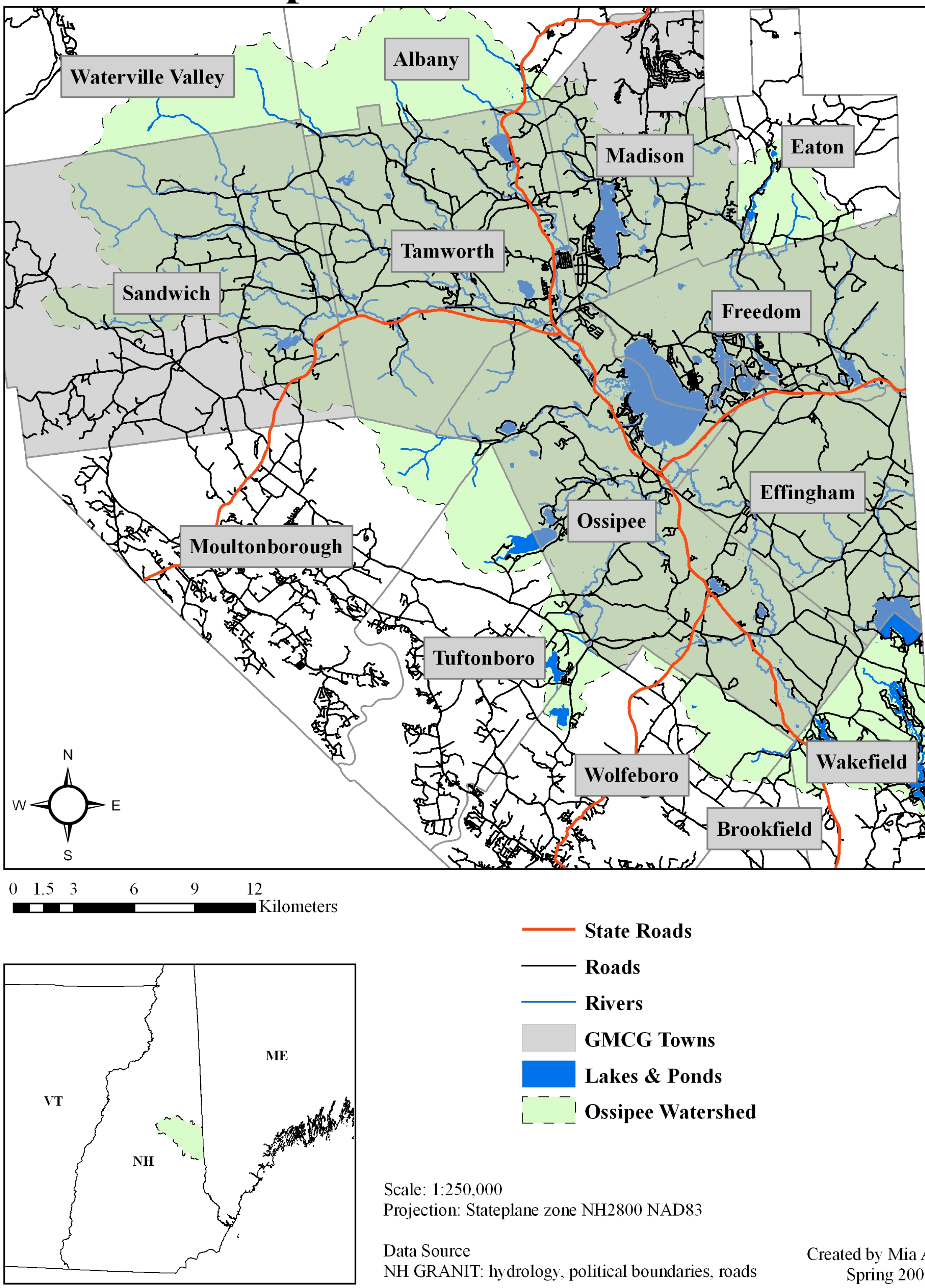
Background

The Ossipee Watershed is a 379 square mile (982 square kilometer) area in east-central New Hampshire defined by Ossipee Lake, located in the center of the watershed, and the Ossipee River, which flows east from the lake to connect with the Saco River in Maine (OWC 2007, Map 1). Although surface hydrology is both diverse and abundant, it is the hidden, groundwater resources that provide significant drinking water sources. In New Hampshire, approximately 60% of the residents rely on groundwater for consumption (SPNHF 1998, Susca 2004). The Ossipee Watershed is representative of the state with a majority of the population utilizing the ground as a source of drinking water; however, the watershed is distinguished by its stratified drift aquifer. Underlying approximately 22% of the watershed land area, this underground reservoir is part of the largest and most productive stratified drift aquifer in New Hampshire (Moore & Medalie 1995a). A stratified drift aquifer comprises layers of sand and gravel deposited by glacial meltwater. Because of the way in which these materials were deposited and the large size of the sand and gravel particles, this aquifer has both a large storage capacity and high recharge rates, which allow precipitation or runoff from the land surface to quickly replenish water supplies (Moore & Medalie 1995a). The characteristics that make the Ossipee Aquifer very productive also make it very vulnerable to pollution from the land surface. Consequently, land use practices in specific parts of the watershed have the potential to significantly impact the drinking water quality.

Water testing results from public and private wells in New Hampshire have demonstrated the increasing impact that land use practices are having on groundwater quality. Radon, arsenic and methyl tertiary-butyl ether (MTBE) have been found in concentrations that exceed maximum contaminant levels (MCLs), levels considered a health risk by the Environmental Protection Agency (EPA) (Susca 2004, Ayotte et al. 2008, Ayotte et al. 2003, Ayotte et al. 2007). Although radon and arsenic come from natural sources, MTBE and other volatile organic compounds are directly linked to anthropogenic sources (Carter et al. 2008). In addition, hazardous substances, such as used oil and gasoline, in quantities less than one gallon can contaminate as much as a million gallons of groundwater (Nixon & Saphores 2007, US EPA 1991b). The potential influence that human actions have on degrading drinking water will only continue to increase with population growth and development pressures.

Population in Carroll County, which includes the Ossipee Watershed, tripled between 1950 and 2003 and is projected to increase another 40% by 2025 (SPNHF 2005, Figure 1). Consistent with population growth trends are increases in housing development. Between 1980 and 2000 housing grew by over 55% in Carroll County and these trends will only continue as population increases (OWC 2007). Population growth and development will not only increase demand for drinking water but also increase the risk of groundwater contamination. Protecting drinking water resources requires proactive approaches that contain potential pollutants at their source and active monitoring of groundwater quality.

Ossipee Watershed Towns



Map 2. New Hampshire towns that are a part of the Ossipee Watershed with the six GMCG towns highlighted in gray.

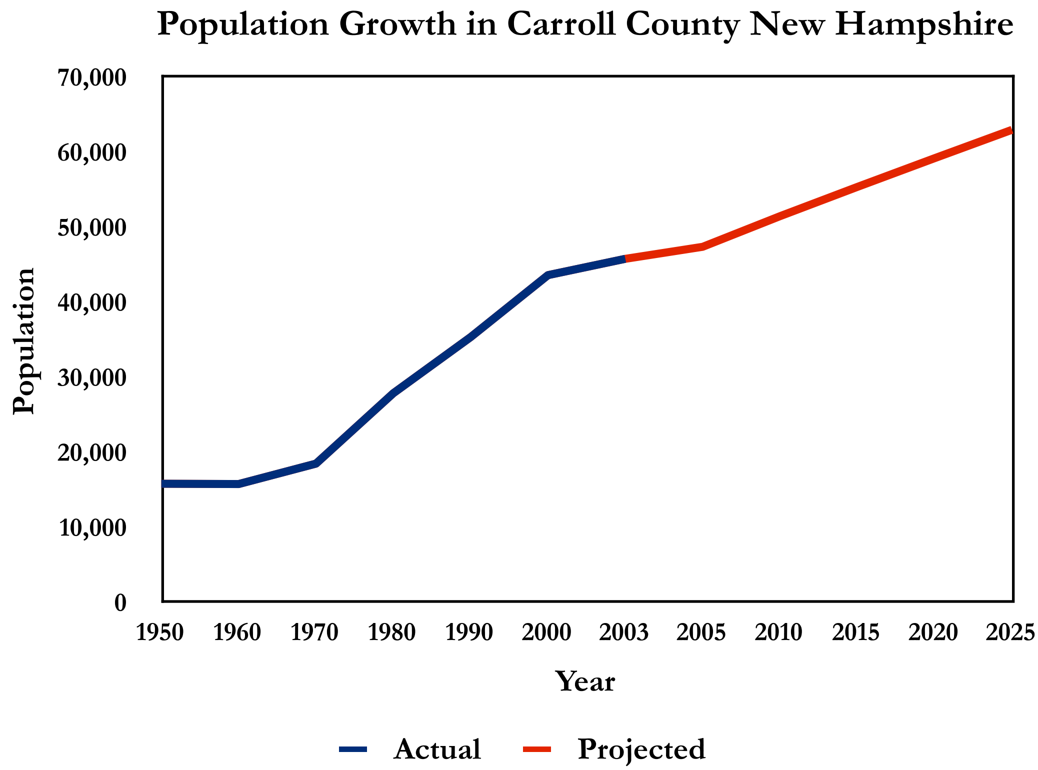


Figure 1. Actual and projected population growth in Carroll County New Hampshire (SPNHF 2005).

Green Mountain Conservation Group

Founded in 1997, the Green Mountain Conservation Group (GMCG) is a non-profit organization focused on protecting the natural resources in the Ossipee Watershed through research, education, advocacy and land conservation (http://www.gmcg.org/). Although the Ossipee Watershed includes 14 towns in New Hampshire, GMCG has chosen to focus on the six major watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich and Tamworth (Map 2). With assistance from the New Hampshire Department of Environmental Services (NH DES), the University of New Hampshire (UNH), and residents of the six watershed towns, GMCG has been monitoring surface water quality since 2002. This water quality monitoring program has expanded over time to include 35 sites along major rivers and streams and several locations on the Ossipee Lake system (http://www.gmcg.org/).

Although surface water quality is important and undeniably linked to groundwater hydrology, the dependence on groundwater as a source of drinking water has influenced GMCG's interest in increasing its focus on groundwater protection. In the future, they plan to add a groundwater monitoring program to their current water quality monitoring efforts. Through a grant from NH DES, GMCG has created its own Source Water Protection Project. Starting in 2007, this grant has helped to: 1) establish the Ossipee Aquifer Steering Committee (OASC), consisting of stakeholders from the six watershed towns, 2) create an inventory of potential contamination sources (PCSs) across the watershed, and 3) provide outreach to area businesses regarding the use of best management practices (BMPs) for groundwater protection.

Definitions

To ensure clarity throughout this report, potentially confusing terms are explained in detail below. These definitions are specific to water resource protection and provide details particular to New Hampshire. Understanding these terms, in this context, will provide greater insight into state regulations and the rationale for incorporating these pre-existing concepts into this project.

Public Water System (PWS)

A public water system in New Hampshire is defined as "a piped water system having its own source of supply, serving 15 or more services or 25 or more people, for 60 or more days per year" (NH DES 1999). Within the classification of PWSs, there are three different categories (Table 1). Each type of PWS has different requirements and responsibilities outlined by the NH DES, ranging from community water systems, which have the strictest water quality monitoring requirements, to transient/non-community water systems that have the fewest sampling requirements. An important distinction between types of PWSs is wellhead protection area (WHPA) requirements. All new C systems are required to have WHPAs, some P systems have WHPAs, and N systems do not have this requirement (NH DES 2007b).

Wellhead Protection Area (WHPA)

A wellhead protection area (WHPA) is "the area surrounding a public water supply well from which water and contaminants are likely to reach the well" (NH DES 2007b, Moore & Medalie 1995b). WHPAs are delineated differently based on the substrate, bedrock, till or gravel, and the daily pumping rate. In the case of bedrock wells, the WHPA is a circle with a radius determined by the maximum daily amount of water withdrawn from the well. This radius ranges from 1,300 to 4,000 feet (396 to 1,219 meters). For till or gravel wells, WHPAs are delineated using existing hydrogeological information, therefore these WHPAs tend to be much more irregular in shape. Within the WHPA there is a much smaller sanitary protective radius, 75 to 400 feet (23 to 122 meters), which the PWS is required to manage through direct ownership or by conservation easements (NH DES 2007g).

Table 1. Definitions and examples of the three types of public water systems that occur in New Hampshire (NH DES 2007c, 2007d, 2007e).

Type of PWS	Definition	Examples
Community (C)	A water system designed to serve at least 25 residents on a year round basis.	• Municipal • Mobile home parks • Apartments/Condominiums • Single family housing developments
Non-Transient/ Non-Community (P)	A water system designed to serve at least 25 people, for at least six months per year.	• Day cares • Schools • Commercial properties
Transient/ Non-Community (N)	A water system designed to serve at least 25 people, for at least 60 days per year.	• Restaurants • Campgrounds • Motels • Recreational areas • Service stations • Dental and medical offices

Potential Contamination Source (PCS)

According to New Hampshire statute RSA 485-C and Env-Wq 401, potential contamination sources (PCSs) are "human activities or operations upon the land surface that pose a foreseeable risk of introducing regulated substances into the environment in such quantities as to degrade the natural groundwater quality." NH DES has divided these PCSs into 19 categories (Table 2). The PCSs highlighted in gray were the focus of GMCG's inventory because of their connection to Env-Wq 401 Best Management Practices for Groundwater Protection.

Table 2. Activities and facilities identified as potential contaminant sources to groundwater quality protection. The 10 PCSs highlighted in gray were the focus of this project (RSA 485-C, Env-Wq 401).

1	Vehicle service and repair shops
2	General service and repair shops
3	Metalworking shops
4	Manufacturing facilities
5	Underground and aboveground storage tanks
6	Waste and scrap processing and storage
7	Transportation corridors
8	Septic systems
9	Laboratories and certain professional offices (medical, dental, veterinary)
10	Use of agricultural chemicals
11	Salt storage and use
12	Snow dumps
13	Stormwater infiltration ponds or leaching catch basins
14	Cleaning services
15	Food processing plants
16	Fueling and maintenance of earth moving equipment
17	Concrete, asphalt, and tar manufacture
18	Cemeteries
19	Hazardous waste facilities

Best Management Practice (BMP)

In New Hampshire, Env-Wq 401 Best Management Practices for Groundwater Protection requires PCSs that use, store or handle regulated substances to implement BMPs. BMPs under this regulation are strategies for preventing the release of hazardous substances into the ground to decrease the potential of groundwater contamination. These BMPs are simple operating practices that include "the use of appropriate containers, labeling on containers, impervious floor surfaces and outdoor storage" (Rigrod 2006). These recommendations are summarized by NH DES in the list that follows (2007a):

A SUMMARY OF BEST MANAGEMENT PRACTICES FOR GROUNDWATER PROTECTION

Storage

- Store regulated substances on an impervious surface.
- Secure storage areas against unauthorized entry.
- Label regulated containers clearly and visibly.
- Inspect storage areas weekly.
- Cover regulated containers in outside storage areas.
- Keep regulated containers that are stored outside more than 50 feet from surface water and storm drains, 75 feet from private wells, and up to 400 feet from public wells.
- Secondary containment is required for regulated containers stored outside, except for on premise use heating fuel tanks, or aboveground or underground storage tanks otherwise regulated.

Handling

- Keep regulated containers closed and sealed.
- Place drip pans under spigots, valves, and pumps.
- Have spill control and containment equipment readily available in all work areas.
- Use funnels and drip pans when transferring regulated substances; perform transfers over impervious surface.

Release Response Information

- Post information on what to do in the event of a spill.

Floor Drains and Work Sinks

- Cannot discharge into or onto the ground.

Project Overview

Having established the importance of groundwater and the Ossipee Watershed context, the next step is to identify strategies for protecting this natural resource. Using the PCS inventory as a starting point, this project investigates methods of prioritizing groundwater protection efforts. The following three sections aim to do this by determining the PCSs that have the greatest risk to drinking water based on their location in the watershed and relationship to public water supplies. Section 1 presents the results of the PCS inventory in the context of town boundaries, aquifer recharge areas, and proximity to public water systems. Section 2 presents the results of the groundwater vulnerability analysis. Section 3 provides recommendations based on results from the previous two sections. The final section summarizes these results and the appendices provide more detailed PCS lists and methods.

SECTION 1: POTENTIAL CONTAMINATION SOURCE INVENTORY AND ASSESSMENT

This section presents the results from "windshield surveys" that identified potential contamination sources in the six watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth. These results are displayed by town, potential contamination source type, relationship to the Ossipee Aquifer, and proximity to public water systems. Appendices A, B, and C have more detailed tables of the information presented in this section.

Potential Contamination Sources

According to the New Hampshire Department of Environmental Services (NH DES), the first step to taking a proactive approach to groundwater protection, after identifying the area in need of protection, is to determine the locations of potential contamination sources (PCSs). During the summer of 2008, with assistance from GMCG and members of the OASC, an inventory of PCSs within the six watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich and Tamworth was completed. Global Positioning System (GPS) coordinates were collected for each PCS location and a Geographic Information System (GIS) data layer was formed. Watershed surveys identified 139 PCSs distributed among the six watershed towns as follows: Effingham 20, Freedom 12, Madison 20, Ossipee 45, Sandwich 8, Tamworth 34 (Table 3, Map 3, Appendix A). These 139 PCSs included 11 of the types identified by NH DES (Table 2, Table 4).

Table 3. Number of potential contamination sources by town.

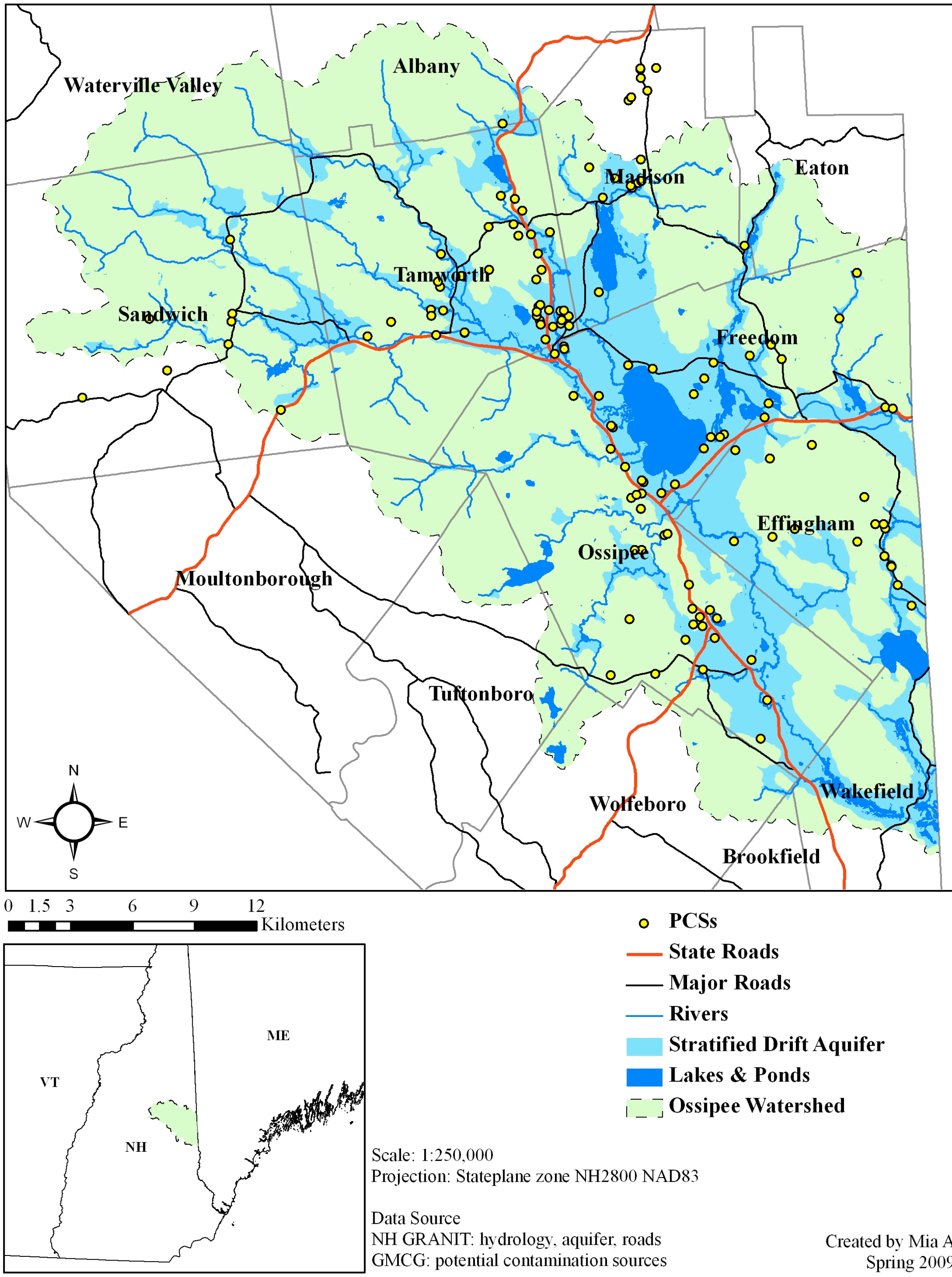
Town	Number of PCSs*
Effingham	20
Freedom	12
Madison	20
Ossipee	45
Sandwich	8
Tamworth	34
	Total = 139

* Includes only the types of PCSs that were the focus of this project, see Table 2.

The three most prevalent PCSs were vehicle service and repair shops (PCS Type 1), underground and aboveground storage tanks (PCS Type 5), and fueling and maintenance of earth moving equipment (PCS Type 16).

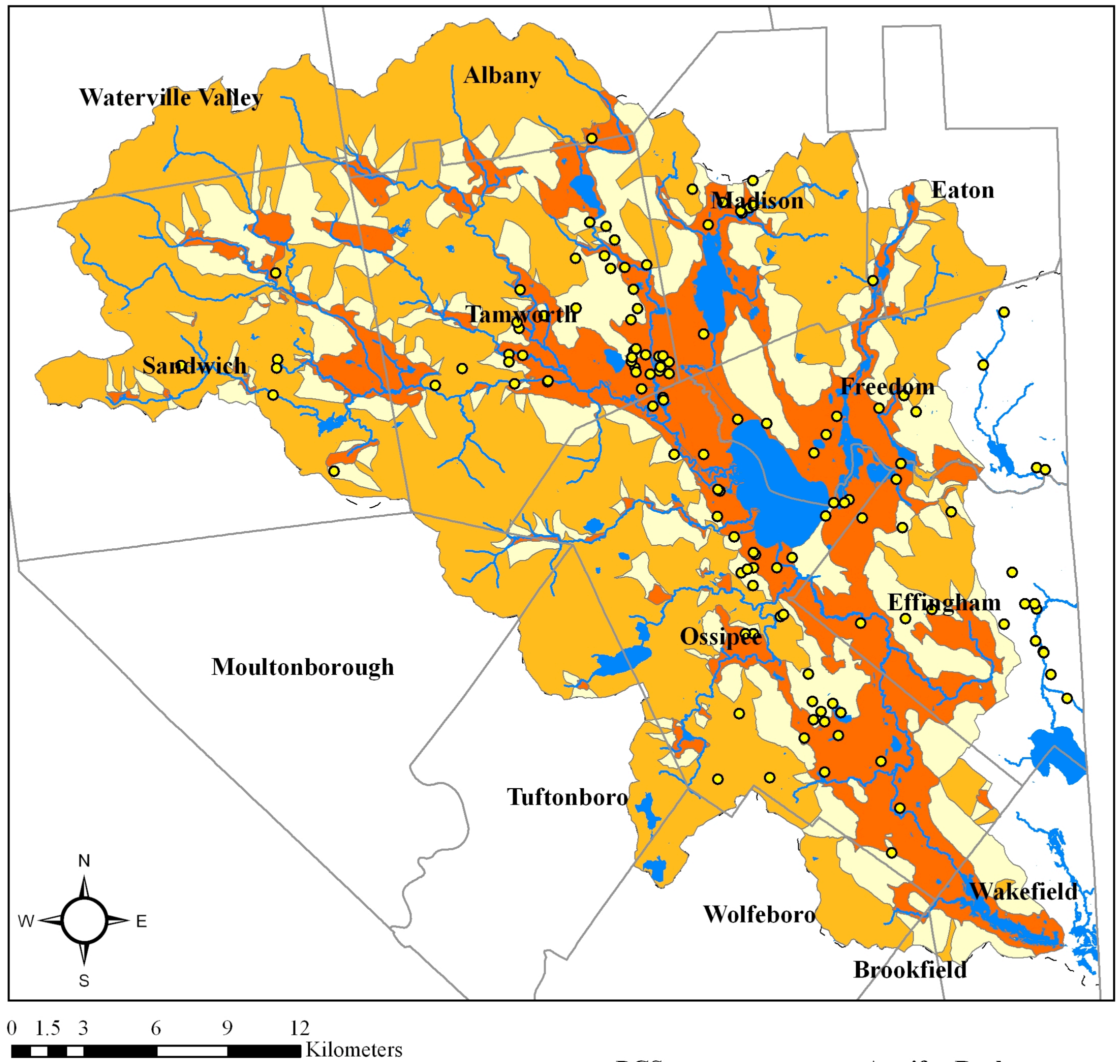
This PCS inventory was conducted with a focus on the towns in partnership with GMCG. Consequently, of the 139 PCSs found across these six watershed towns, 129 exist within the Ossipee Watershed.

Potential Contamination Sources in the Six GMCG Towns



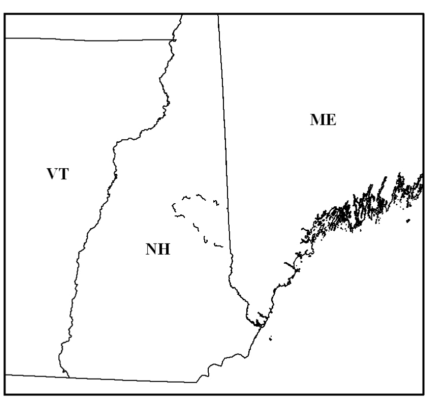
Map 3. Potential contamination sources in the six Ossipee Watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth.

Potential Contamination Sources and Aquifer Recharge Areas



PCSs
Rivers
Ossipee Watershed
Lakes & Ponds

Aquifer Recharge
Primary
Secondary
Tertiary



Scale: 1:250,000
Projection: Stateplane zone NH2800 NAD83

Data Source
NH GRANIT: hydrology
GMCG: potential contamination sources
Mattison & Newton 2001: recharge areas

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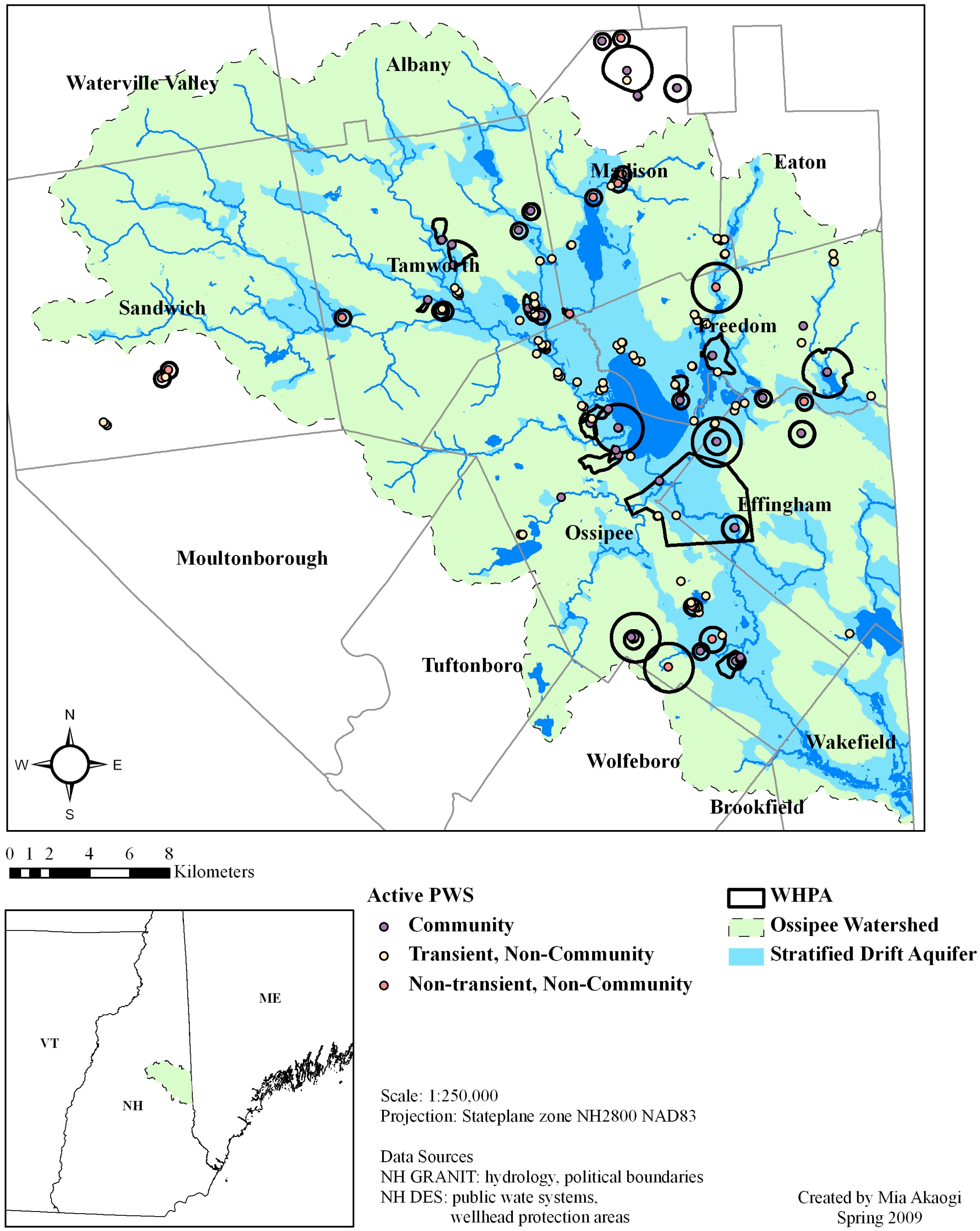
Spring 2009

Map 4. Potential contamination sources in the Ossipee Watershed shown with aquifer recharge areas.

Public Water Systems and Wellhead Protection Areas



Map 5: Active public water systems in the towns of Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth with their corresponding wellhead protection areas.

Table 4. Number of potential contamination sources by type and town.

	PCS Type										
Town	**1**	**2**	**4**	**5**	**6**	**9**	**10**	**14**	**16**	**17**	**19**
Effingham	2			5			1	1	10	1	
Freedom	2			7					2		1
Madison	4	2	3	8					3		
Ossipee	12		2	23	2			1	5		
Sandwich	1			2	1	1		1	2		
Tamworth	12	3		10	3			1	5		
TOTALS	**33**	**5**	**5**	**55**	**6**	**1**	**1**	**4**	**27**	**1**	**1**

TOTAL = 139

Potential Contamination Sources and the Ossipee Aquifer

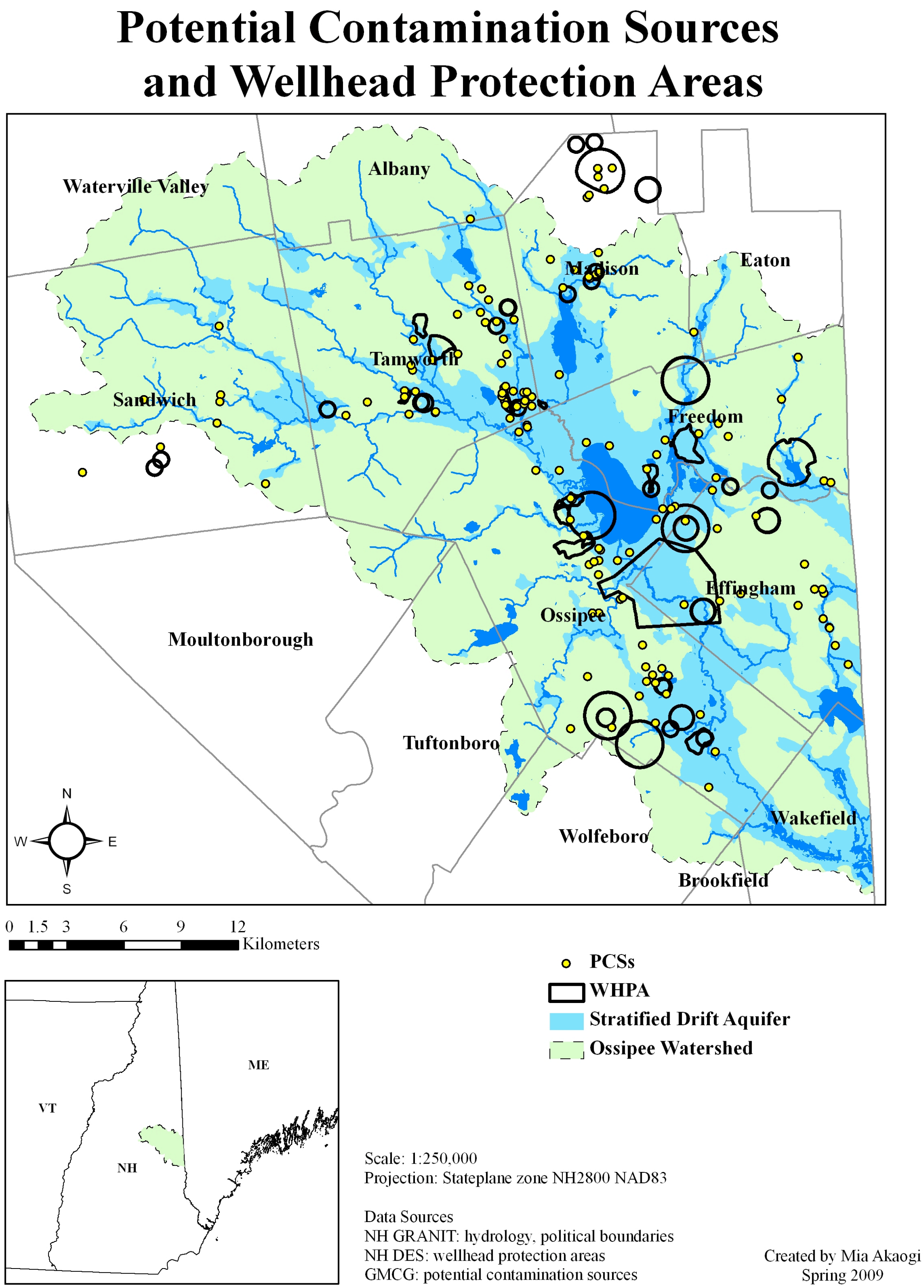
Of the PCSs that exist within the Ossipee Watershed, 76 are located over the Ossipee Aquifer (Table 5, Appendix B).

Table 5. Number of potential contamination sources that are located over the Ossipee Aquifer by town.

Town	Number of PCSs
Effingham	10
Freedom	10
Madison	11
Ossipee	24
Sandwich	0
Tamworth	21
	Total = 76

Although it is useful to know how many PCSs exist over the Ossipee Aquifer, it is also important to consider recharge areas. Watersheds are often divided into primary, secondary, and tertiary aquifer recharge areas. Primary recharge areas exist where aquifer materials are exposed at the land surface and where surface water and runoff directly infiltrate the ground and recharge the aquifer (OWC 2007). Secondary recharge areas are zones adjacent to the aquifer where surface water and groundwater flow into primary recharge areas (OWC 2007). Tertiary recharge areas "supply water to streams that flow across primary recharge areas, and may or may not recharge the aquifer depending on water levels" (OWC 2007). An analysis of aquifer recharge areas in the Ossipee Watershed can be found in a report completed by Mattison and Newton in 2001.

Based on the map of aquifer recharge areas, 62 PCSs are located over primary recharge, 35 PCSs are located over secondary recharge, and 17 PCSs are located over tertiary recharge (Table 6, Map 4, Appendix B). Recharge areas were not delineated for the entire Ossipee Watershed and consequently, this data does not include all 129 PCSs (Mattison & Newton 2001). However, because primary and secondary recharge areas are closely linked to land use activities and therefore groundwater quality, the PCSs found in these areas are priorities for groundwater protection efforts.



Map 6: Potential contamination sources and wellhead protection areas in Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth.

Table 6. Number of potential contamination sources within primary, secondary, and tertiary aquifer recharge areas by town.

Town	Primary Recharge	Secondary Recharge	Tertiary Recharge
Effingham	9		
Freedom	8		
Madison		4	8
Ossipee	42	2	1
Sandwich	2	4	
Tamworth	1	25	8
TOTALS	**62**	**35**	**17**

TOTAL = 114

Potential Contamination Sources and Public Water Systems

Public water systems (PWSs) are a logical starting point for determining the connections between PCSs and drinking water because of the attention state environmental agencies place on these wells. WHPAs, because they are already defined for community (C) and non-community/ non-transient (P) public water supply wells, are a useful tool for monitoring land use practices in close proximity to drinking water sources. According to NH DES there are 193 active PWS wells in the watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich and Tamworth (Map 5). Of these 193 wells, 54 have designated WHPAs; 16 of which have PCSs. In total, 29 PCSs exist within WHPAs (Table 7, Map 6, Appendix C). The Village District of Eidelweiss and White Lake Estates have the largest number of PCSs within their WHPAs, 6 and 5 respectively. Although Eidelweiss is important within the context of the town of Madison, it is important to note that it is not located within the Ossipee Watershed.

Although this is a useful strategy for recognizing watershed areas with a high potential for water pollution, PWSs are not the only system for obtaining drinking water in the Ossipee Watershed. This prioritization strategy only accounts for a limited percentage of the population, only a few of the drinking water wells in the watershed. Consequently, another method is needed to determine how best to protect private wells and public wells that don't have WHPAs.

Table 7. Number of potential contamination sources that are located within wellhead protection areas by public water system.

Public Water System	Number of PCSs Within WHPA
Bluffs at Ossipee Lake	2
Carroll County Complex	1
Chick Packaging Inc.	1
Chocorua Woods	1
Deer Cove Water Co.	2
Lakeview Neurorehab Center	1
Maclean Precision Mach. Co. Inc.	2
Madison Elementary School	2
Ocean State Job Lot	1
Ossipee Water Dept.	1
Pine Landing Condominium	1
Ryefield Village	1
Tamworth Mobile Home Park	1
Tamworth Pines Coop	1
Village District of Eidelweiss	6
White Lake Estates	5
	Total = 29

Many residents are not connected to PWSs and get their drinking water from private wells. NH DES began its private well inventory in 1984 and there are currently 3,190 records of private wells in the Ossipee Watershed (B. Kernen, personal communication, August 13, 2008). In order to map these wells with GIS software, GPS coordinates are needed. However, only a third of these wells have GPS coordinates. Because there are thousands of drinking water sources and the private well data-set is incomplete, using well locations to define priority areas for groundwater protection is difficult. Consequently, a watershed-wide analysis method that incorporates the locations of PCSs is needed to determine which areas of the Ossipee Watershed have the highest potential for pollution. Groundwater vulnerability is a concept that can be used in this context.

SECTION 2: GROUNDWATER VULNERABILITY ANALYSIS

This section briefly explains the concept of groundwater vulnerability and the modified groundwater vulnerability analysis used in this project. Due to the differences between groundwater flow within the aquifer and outside of it, a separate analysis was done to incorporate the potential for surface water contamination. All analyses were completed on ArcGIS software and detailed explanations of the methods can be found in Appendix D.

Groundwater Flow

To understand how groundwater vulnerability is determined, an explanation of groundwater flow is necessary. Groundwater flows in three dimensions from regions of recharge to regions of discharge. Recharge occurs everywhere that precipitation falls on the land surface and soaks through the ground and discharge occurs where groundwater comes to the land surface to join lakes, streams, and other water bodies (Focazio et al. 2002). Wells that pump significant quantities of water can also become important discharge points.

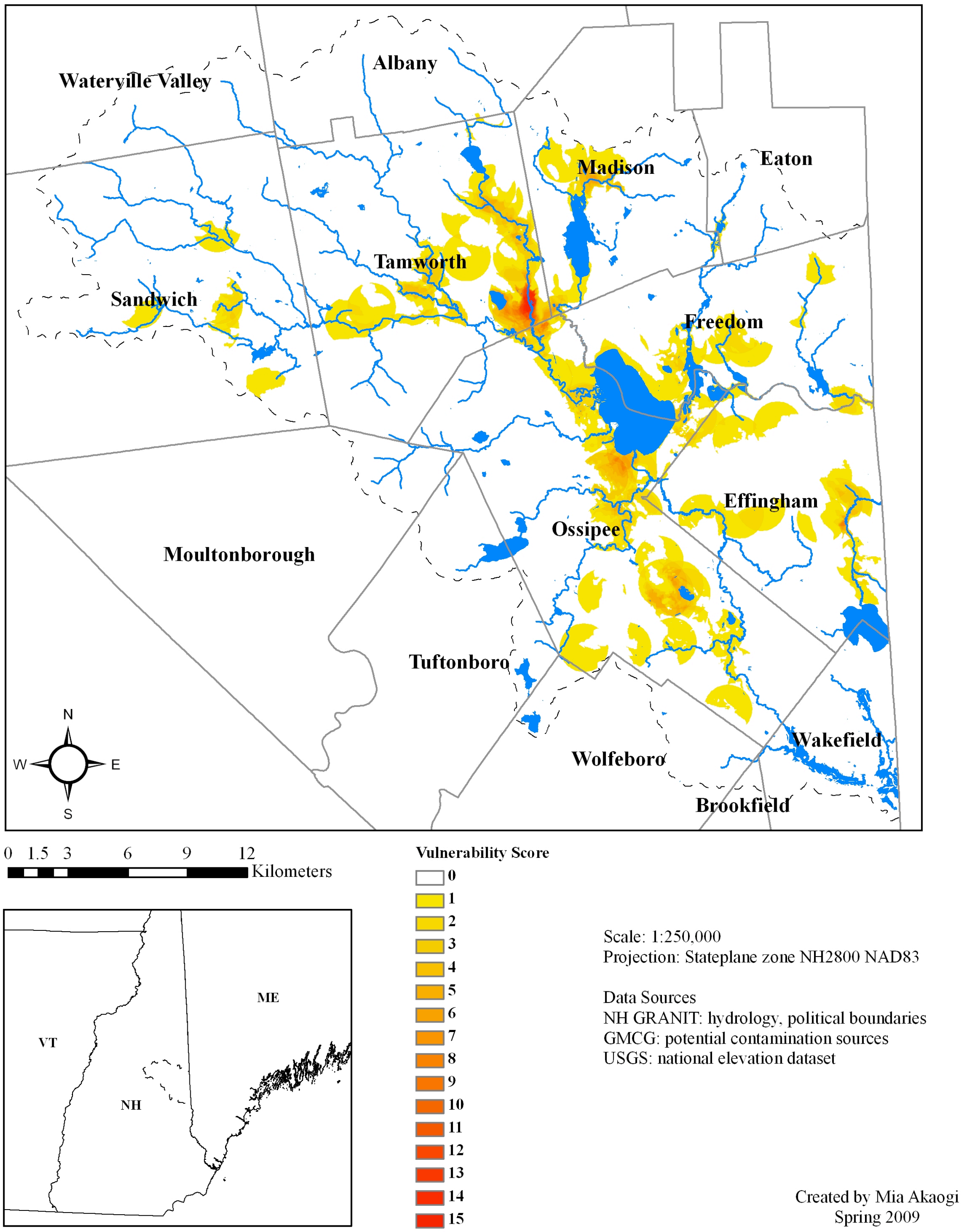
In addition to the general path of water flow between areas of groundwater recharge and discharge, the direction and speed at which water moves is influenced by the soil and aquifer materials. Aquifers are often categorized by unconsolidated (sands and gravels) and consolidated (bedrock) material.

The Ossipee Watershed has both bedrock and sand and gravel aquifers. The Ossipee Aquifer is a stratified drift aquifer that is made up of layers of sand and gravel. Outside and underneath this designated aquifer area, there are also bedrock aquifers. In addition, bedrock aquifers can be found underneath the stratified drift aquifer in some locations. Due to the complexity of groundwater flow both vertically (from the land surface to the saturated water level) and horizontally (within and between aquifers), it is a challenge to determine the effects of PCSs on drinking water quality.

Groundwater Vulnerability

Groundwater vulnerability to contamination has been defined by the National Research Council as " the tendency or likelihood for contaminants to reach a specified position in the ground water system after introduction at some location above the uppermost aquifer" (1993). Most groundwater vulnerability analyses take into account both 1) physical factors that influence water flow to and within an aquifer, and 2) the location and characteristics of a particular contaminant (Focazio et al. 2002). In the Ossipee Watershed, the basis for the groundwater vulnerability analysis is that water flow to and within the aquifer is relatively rapid and therefore the location of the PCSs has greater significance. Although many of the PCSs have similar contaminant concerns, this vulnerability analysis did not focus on one type of pollution. Given assumptions about groundwater flow direction, groundwater vulnerability was calculated by first identifying the potential contamination zone for each PCS.

Groundwater Vulnerability Scores in the Ossipee Watershed



Map 7. Groundwater vulnerability scores based on the locations of potential contamination sources in the Ossipee Watershed.

Potential Contamination Zones

Calculating groundwater flow is a complex process that requires extensive information and modeling software (Watkins et al. 1996). Consequently, to determine the potential contaminant path for each PCS, a simpler method was used based on assumptions of water flow. In general, water flows from higher to lower elevations, and therefore topography can provide a first approximation of groundwater flow direction. However, in the Ossipee Watershed conditions are complicated by differences in substrate within and outside the aquifer area. Within the aquifer area, the substrate is made up of layers of sand and gravel that allow water to flow more quickly vertically, through the unsaturated zone, and once reaching the aquifer may flow horizontally (Moore & Medalie 1995a). In contrast, outside the aquifer, the substrate is more inconsistent, varying from areas with glacial till to areas where the bedrock is close to the land surface (OWC 2007). In these situations, it is possible for water to flow either laterally, along or parallel to the land surface, or vertically depending on local conditions.

An initial analysis examined all the PCSs and assumed that elevations below the PCS would be a part of the potential contamination zone. To create a spatial boundary for the analysis and ensure this zone was manageable, it was limited to a radius of 4,000 feet (1,219 meters). This buffer distance was taken from NH DES requirements for PWSs and is the maximum radius for WHPAs. Other New England states have maximum WHPA requirements that range from 3,000 feet (914 meters) in Vermont to 2,640 feet (805 meters) in Massachusetts (ANR VT DEC 1997, MA DEP 2001). When compared to the WHPA requirements of these other states, New Hampshire is well above average.

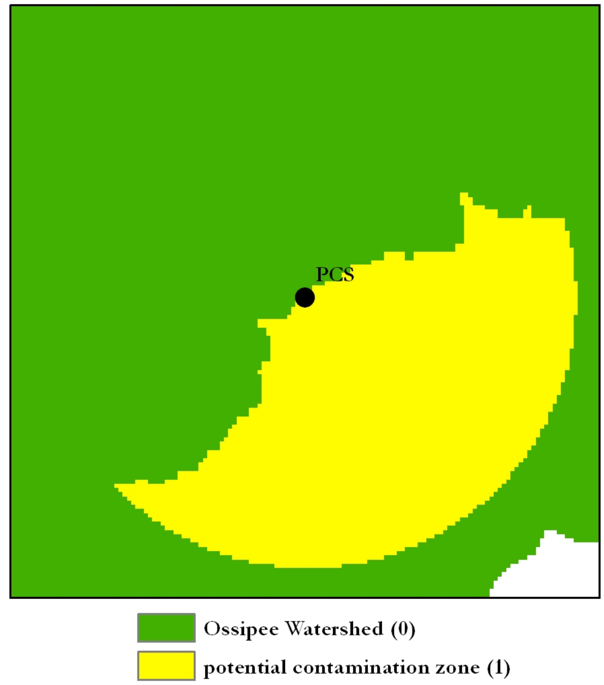


Figure 2. Example of 4,000 foot (1,219 meter) radius buffer around a PCS and its potential contamination zone in yellow. See Appendix D for a step by step description of how this potential contamination zone was calculated.

From a digital elevation model, the land area below each PCS and within a 4,000 foot radius was determined. Figure 2 shows an example of a potential contamination zone, in yellow, for a PCS. Basically, the potential contamination zone shows the area where the PCS could have a negative impact on groundwater quality and any drinking water wells that exist in that region. Appendix D describes in more detail how the potential contamination zone was calculated for each PCS.

Analysis Results

To prioritize groundwater monitoring efforts, it is necessary to know which sections of the watershed have the highest potential risk of groundwater contamination from PCSs. A potential contamination zone was calculated for each PCS and these areas were added to determine an assessment of groundwater vulnerability across the watershed (Appendix D). Vulnerability scores ranged from 0-15 (Map 7).

A vulnerability score of 15 means that the potential contamination zones of 15 PCSs overlapped at that point. The area of the Ossipee Watershed with the highest vulnerability scores is located in the southeast corner of Tamworth. These high vulnerability scores can be explained by the density of PCSs that exist along this stretch of Route 16, one of the busiest state roads in New Hampshire (Map 3).

Examining groundwater vulnerability by town shows some interesting trends (Table 8). Once again, it is easy to see that Tamworth has the highest groundwater vulnerability scores. However, Ossipee had the highest percentage of land area considered vulnerable, almost a third of the town. In comparison, only about a quarter of Tamworth is at risk for groundwater contamination, this risk is therefore more concentrated. In stark contrast, both Sandwich and Freedom had the lowest vulnerability scores, with a maximum of 3 and 4 respectively. Additionally, less than 8% of the land area in Sandwich had any potential risk to groundwater contamination.

Table 8. Groundwater vulnerability for Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth shown in acres and percent of the town.

	Effingham		Freedom		Madison		Ossipee		Sandwich		Tamworth	
Score	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
0	21,467	76.64%	21,104	79.61%	16,389	83.37%	38,089	72.29%	32,946	92.91%	32,696	76.85%
1	4,699	16.78%	3,936	14.85%	2,489	12.66%	8,974	17.03%	2,140	6.04%	5,391	12.67%
2	1,345	4.80%	1,233	4.65%	225	1.14%	2,296	4.36%	346	0.98%	1,526	3.59%
3	350	1.25%	165	0.62%	114	0.58%	1,670	3.17%	27	0.08%	1,218	2.86%
4	91	0.33%	71	0.27%	291	1.48%	859	1.63%			626	1.47%
5	24	0.09%			98	0.50%	517	0.98%			279	0.66%
6	13	0.04%			53	0.27%	190	0.36%			250	0.59%
7	10	0.03%					52	0.10%			173	0.41%
8	13	0.05%					38	0.07%			59	0.14%
9							5	0.01%			43	0.10%
10											33	0.08%
11											43	0.10%
12											51	0.12%
13											46	0.11%
14											66	0.16%
15											44	0.10%

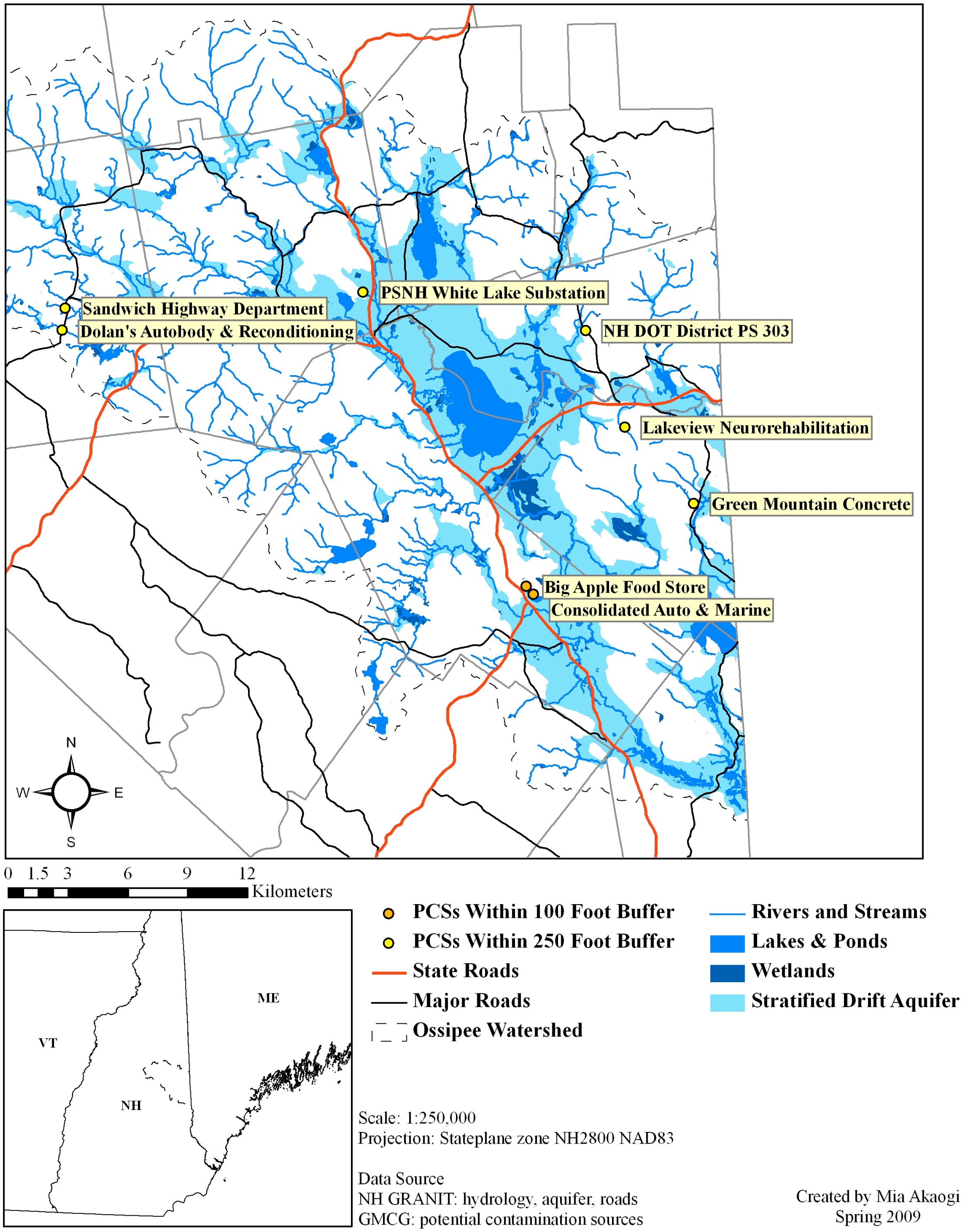
Potential Contamination Outside the Ossipee Aquifer

As mentioned previously, outside of the Ossipee Aquifer area, water flow is less predictable and there is greater potential for surface runoff because the soils tend to be less porous. In this scenario the risk comes from surface water features that are contaminated by runoff from a PCS. Because surface water and groundwater are hydrologically linked, there is a possibility for a polluted surface water feature to contaminate groundwater (Winter et al. 1998). To determine if this concern is justified for any of the PCSs outside the aquifer area, a separate analysis was conducted.

Efforts to protect rivers and lakes often attempt to define the buffer width necessary to prevent water contamination. The riparian zone is used to describe this region adjacent to rivers and streams and riparian buffer refers to the width needed to protect water quality. Definitions of what constitutes an adequate riparian buffer vary among authors and pollution type. However, a common figure is 100 feet (30 meters) (Wenger 1999). For the Ossipee Watershed, all surface water features were buffered by 100 feet (30 meters). Out of the 53 PCSs that occur outside the Ossipee Aquifer, only two were found within the 100 foot (30 meter) surface water buffer (Table 9, Map 8). The Big Apple Store and Consolidated Auto and Marine are located near Duncan Lake which flows into the Pine River. The Pine River eventually drains into Ossipee Lake and the Ossipee River.

A 100 foot (30 meter) buffer is used mainly in the context of rivers and streams, and so, another analysis was done using buffer width information obtained from New Hampshire state environmental regulations. Recently updated, the Comprehensive Shoreland Protection Act has identified three zones around all major rivers and lakes. These buffer zones of 50 feet (15 meters), 150 feet (46 meters), and 250 feet (76 meters) have land use restrictions that have been enacted for the protection of water quality. The 250 foot (76 meter) buffer, also know as the "Protected Shoreland", prevents the construction of new auto salvage yards and solid waste and hazardous waste facilities because of the potential contaminants that these activities emit (NH DES 2008b). Many of the PCSs found in the Ossipee Watershed have similar contaminant concerns and therefore, in regard to the potential risk to water quality, should be considered equally. Consequently, using this more conservative 250 foot (76 meter) buffer resulted in 8 PCSs, including the 2 located within the 100 foot (30 meter) buffer (Table 9, Map 8).

Potential Contamination Sources Within 100 and 250 feet of Surface Hydrology



Map 8. Potential contamination sources outside the aquifer and that are within 100 feet (30 meters) or 250 feet (76 meters) of a river, stream, lake, or pond in the Ossipee Watershed.

Table 9. List of potential contamination sources located within 100 feet (highlighted in gray) and 250 feet of surface water body (river, stream, lake, pond, wetland) in the Ossipee Watershed.

Town	Name	PCS Type	Surface Water Feature
Effingham	Green Mountain Concrete	17	Unnamed swamp/marsh connected to Salmon Brook
Effingham	Lakeview Neurorehabilitation	5	Hodgedon Brook
Freedom	NH DOT District PS 303	5	Unnamed tributary of Square Brook
Ossipee	Big Apple Food Store	5	Frenchman's Brook, tributary of the Pine River
Ossipee	Consolidated Auto & Marine	16	Duncan Lake
Sandwich	Dolan's Autobody & Reconditioning	1	Bearcamp River
Sandwich	Sandwich Highway Department	5	Unnamed tributary of Heath Brook
Tamworth	PSNH White Lake Substation	5	Unnamed pond that flows into a tributary of the Chocorua River

Based on assumptions of groundwater flow and the locations of PCSs, priorities in the Ossipee Watershed were identified. Results from the groundwater vulnerability analysis ranked the watershed areas based on potential risk of contamination by PCSs. The regions with the highest vulnerability scores would be an important priority for any water quality monitoring conducted in the Ossipee Watershed. The surface water analysis for PCSs located outside the aquifer prioritize sites important for BMP outreach, education, and implementation. Both of these strategies, the groundwater vulnerability analysis and surface water analysis, are useful to residents in the watershed to prioritize where and how to place conservation efforts.

SECTION 3: CONSIDERATIONS AND RECOMMENDATIONS

This section provides recommendations of priority potential contamination sources based on their type and relationship to the Ossipee Aquifer and public water systems. In an attempt to address private well owners, an example is presented with a process for evaluating potential concerns. Based on the vulnerability analysis, recommendations for where and how to implement a groundwater quality monitoring program are included.

Priority Potential Contamination Sources

Public Outreach and Education

Of the 11 types of PCSs found in the Ossipee Watershed, the three most prevalent are: vehicle service and repair shops (1), underground and aboveground storage tanks (5), and fueling and maintenance of earth moving equipment (16) (Table 2, Table 4). As a result, it would be important to provide educational information to the public regarding proper management of these facilities.

For vehicle service and repair shops, a primary concern is the proper disposal of used oil, antifreeze, and other automotive fluids. "Used oil is the 'single largest environmentally hazardous recyclable material'" and consequently important due to its ability to pollute water resources (Nixon 2007). In addition, current data show that "only half of all used oil is recycled" (Nixon 2007). Even though antifreeze can also be recycled, only 12% of the amount sold yearly is recycled (Nixon 2007). Providing information on where and how to recycle used oil and antifreeze would be useful for both repair shops and excavators and contractors.

Leaking underground storage tanks (USTs) are one of the main reasons for the presence of petroleum products in groundwater. Although technology has greatly improved since the 1980's when USTs were made of untreated steel that corroded over time, new USTs still have been shown to leak (Nixon 2007, ME DEP 2002). In 2003, a study conducted in Rockingham County, New Hampshire found that of the 225 water supply wells tested, 40% had detectable levels of MTBE and that the concentration of MTBE correlated with proximity to USTs (NH DES 2007f). A study in Maine found that the average distance traveled by gasoline constituents, diesel/fuel oil constituents, and MTBE was 295 (90), 140 (43), and 300 (91) feet (meters), respectively (ME DEP 2002). The ability of these organic compounds to travel through the ground and contaminate aquifers is a significant human health concern. Because local level management is often more effective than top-down policy implementation, it is recommended that GMCG and watershed towns work in collaboration with PCSs that have USTs to ensure that they know the proper methods of maintaining these facilities. If there is concern of a leaking UST, resources are available through the US Energy Policy Act of 2005, which target leak prevention and has increased the leaking UST Trust Fund (Nixon 2007).

NH DES recognizes that many contractors and excavators do not have permanent facilities, but often fuel and maintain their equipment in the field, and has published specific BMP recommendations for these situations. These recommendations follow many of the general requirements in Env-Wq 401 and a summary of these suggestions are:

1) Store fuels and fluids in sealed, clearly labeled containers.
2) Keep containers on stable, impervious surface.
3) Provide secondary containment.
4) Keep containers covered.
5) Keep storage areas secure.
6) Keep containers away from surface waters and public water supply wells.
7) Use drip pans under spigots, valves and pumps to catch leaks and spills.
8) Prevent spills when fueling vehicles or transferring fluids from one container to another.
9) Train employees to prevent, contain, and cleanup spills.
10) Properly store and dispose of contaminated soil and materials.
11) Immediately report significant or uncontrolled spills.

More detailed information can be found in the NH DES publication Best management practices for fueling and maintenance of excavation and earthmoving equipment (2008a).

Best Management Practice Implementation

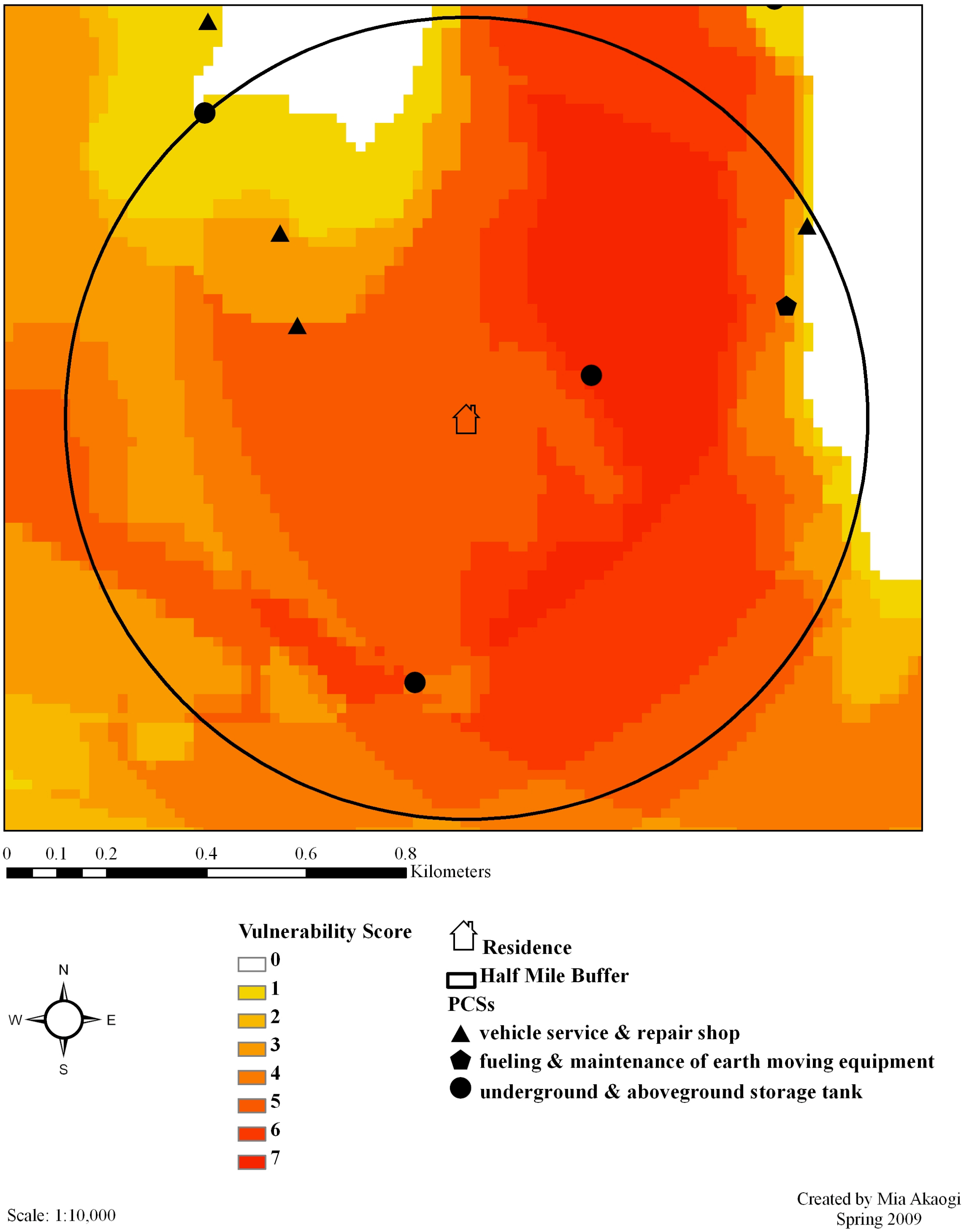
In general, it is recommended that GMCG and the watershed towns focus on encouraging the use of BMPs at PCSs that are located above primary recharge areas (Table 6, Appendix B). However, this still includes a list of over 60 PCSs. To prioritize groundwater protection efforts further, these PCSs were compared with those found within WHPAs and the list was condensed to 17 (Table 10). Almost all these PCSs fall into the three major PCS Types (1, 5, and 16 of Table 2) found in the Ossipee Watershed, which adds to their significance.

When taking into account PCSs that could threaten surface water resources, the 8 located within the 250 foot (76 meter) buffer are significant (Table 9). If further prioritization is necessary, it would be important to focus on PCSs that have USTs and are within 75 feet (23 meters) of a surface water resource. New Hampshire has recently updated its UST setback requirements for new sites and now requires 75 feet (23 meters) between an UST and a surface water resource (NH DES 2007f). Even though, the Big Apple Store is within 75 feet (23 meters) of Frenchman's Brook it only has aboveground storage tanks and is therefore not as high a priority as it would be if it had USTs. However, proximity to Frenchman's Brook is a crucial factor and it would be important to make sure that BMPs are implemented and maintained at this business over time.

Table 10. Potential contamination sources found within primary aquifer recharge areas and wellhead protection areas in the Ossipee Watershed.

Town	Name	PCS Type 1	PCS Type 2
Effingham	Individual Business Owner	16	
Freedom	Kondrat Kustoms	1	
Madison	Chick Packaging Inc	4	5
Madison	Department of Public Works Garage	1	
Madison	Maclean Precision Machine Company Inc	4	
Madison	Madison Town Garage/Highway Garage	5	1
Madison	Marson's RV Repairs	1	
Madison	Verrochi Contractors	16	
Ossipee	Andrea & Jim's Automotive Repair	1	
Ossipee	Brooks Motor Sales	1	
Ossipee	Carroll County Oil	5	
Ossipee	Pinetree Power Tamworth Power Station	5	
Ossipee	Ward's Boat Shop Inc	1	
Tamworth	General Custom & Repair Auto	1	
Tamworth	Miller's Route 16 Superstore	1	
Tamworth	State Police/Registry of Motor Vehicles	5	
Tamworth	Tice's Automotive Service	1	

Groundwater Vulnerability Scores for an Example Residence



Map 9. Example of a private residence and PCSs and groundwater vulnerability scores within a half mile radius.

Example for a Private Well Owner

Groundwater Vulnerability and PCS Inventory

The groundwater vulnerability analysis was conducted to provide necessary information for all drinking water wells, not just those associated with PWSs. Consequently, Map 9 depicts an example private residence that has its own drinking water well and how groundwater vulnerability information and the PCS inventory can be used to make informed decisions about protecting drinking water quality. In this example, the house is located within a region that has a groundwater vulnerability score of 5, symbolizing the 5 surrounding PCSs that could potentially impact the private well (Map 9). Surrounding the home are 7 PCSs, 3 of which are vehicle service and repair shops, 3 that are underground or aboveground storage tanks and 1 that is an operation that requires fueling and maintenance of earth moving equipment. The potential pollutants associated with these land use activities are outlined in Table 11. For all three of these PCSs, the majority of the potential pollutants are considered organic compounds.

Private Well Sampling Recommendations

In New Hampshire, there are no state requirements for private well testing. However, NH DES has certain water quality testing recommendations for private well owners outlined by contaminant type and testing frequency (Figure 3). In publications, NH DES does not place volatile organic compounds (VOCs) high on the priority list for water testing. Additionally, the recommendation is only once every 5-10 years. Yet, in this example, where the majority of the potential contaminants are VOCs, it would be wise to place precedence on testing for these chemicals and/or increase the frequency of sampling.

Contaminants & Testing Frequency

Standard Analysis	Testing Frequency
Arsenic Bacteria Chloride Copper Fluoride Hardness Iron Lead Manganese Nitrate/Nitrite pH Sodium	Every 3-5 yrs (except for bacteria and nitrate which are yearly)
Radiological Analysis	Every 3-5 yrs
Radon Uranium Analytical Gross Alpha	
VOCs	Every 5-10 yrs

Figure 3. NH DES's water quality testing recommendations for a private well owner (NH DES 2008c).

Table 11. Potential pollutants associated with the PCSs found near an example drinking water well (US EPA 1991a).

PCS Type	Potential Pollutants
vehicle service and repair shop (1)	• motor oil • antifreeze/radiator coolant • transmission fluid • brake fluid • solvents • acids
underground and aboveground storage tank (5)	• gasoline and associated additives (including MTBE) • oil
fueling and maintenance of earth moving equipment (16)	• gasoline • motor oil • lubricants • antifreeze/radiator coolant • transmission fluid • brake fluid

Potential Groundwater Monitoring Wells

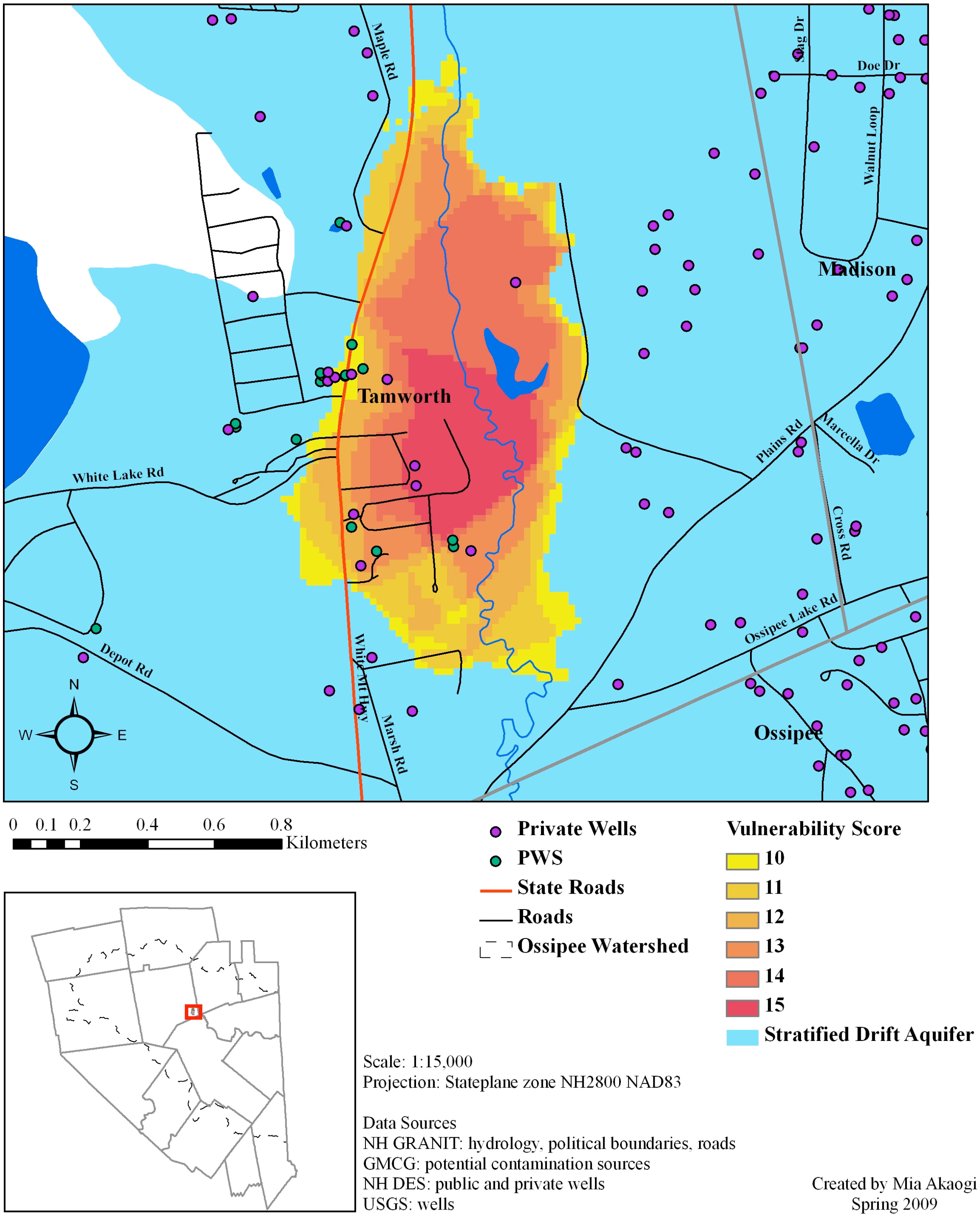
To support GMCG's desire to initiate a groundwater monitoring program, the vulnerability scores were used to identify locations in the Ossipee Watershed that would be most important for drinking water protection. Limiting vulnerability to scores between 10 and 15 highlights the watershed area with the highest risk of groundwater contamination. This places priority on the southeastern corner of Tamworth as a potential monitoring area (Map 10). This region had the highest vulnerability scores across the entire watershed, while no other town had scores greater than 9 (Table 8). The 15 PCSs that contributed to these high vulnerability scores in Tamworth are listed in Table 12. All these PCSs fall into the three major types found in the Ossipee Watershed: vehicle service and repair shops (1), underground and aboveground storage tanks (5), and fueling and maintenance of earth moving equipment (16). The potential chemicals associated with these PCSs are identified in Table 11 and fall under the category of VOCs.

Table 12. List of potential contamination sources that contribute to the high groundwater vulnerability scores in Map 10.

Town	Name	PCS Type
Madison	Madison Lumber Mill Inc	5
Ossipee	Builders & Homeowners Mortgage Corp	16
Ossipee	Maingas Propane	5
Ossipee	Pinetree Power Tamworth Power Station	5
Tamworth	Cross Way Repair	1
Tamworth	Falcon Petroleum LLC	5
Tamworth	General Custom & Repair Auto	1
Tamworth	Jon Cyr & Son Excavating	16
Tamworth	Miller's Route 16 Superstore	1
Tamworth	Munces Konvenience/Market in the Pines/Citgo Gas	5
Tamworth	PSNH White Lake Substation	5
Tamworth	Shawn's Auto Repair Service	1
Tamworth	State Police/Registry of Motor Vehicles	5
Tamworth	Tice's Automotive Service	1
Tamworth	Timberline Auto Body Inc	1

Constructing new wells for monitoring is expensive; and because there are already thousands of wells in the Ossipee Watershed, it would be most efficient to leverage this existing resource. Examination of private, public and United States Geological Survey (USGS) wells determined that there are 5 PWS wells and 9 private wells that could be used for water quality monitoring (Appendix E). Of the PWSs that have wells in this area, only one, Tamworth Pines Coop, is a community water system. Community PWSs are already required to test for a range of chemicals by the state of New Hampshire including VOCs (Figure 4). Working with Tamworth Pines Coop would be an easy first step. In addition, Tamworth Pines Coop is one of the PWSs that has a PCS within its WHPA and initiating a partnership would be mutually beneficial.

Area with the Greatest Groundwater Vulnerability in the Ossipee Watershed



Map 10. Area of the Ossipee Watershed with the highest groundwater vulnerability scores, ranging from 10 to 15, and potential groundwater monitoring wells based on existing private, PWS, USGS wells.

Small Community Public Water System's Sampling Schedule Fees		
Test	**Sampling Schedules**	**Average Pricing**
Bacterial	Monthly, Quarterly, or Semi-Annually	$ 24.00
Lead	Semi Annual	$ 22.00
Copper	Semi Annual	$ 22.00
Nitrates	Every Three Years	$ 16.00
Nitrites	Every Three Years	$ 16.00
IOC (Inorganic)	Every Three Years	$ 310.00
SOC (Synthetic)	Annually (2)	$ 650.00
VOC (Volatile)	Annually (1, 2)	$ 120.00
Uranium Mass	1,3	$ 50.00
Combined Radium	1,3	$ 150.00
Compliance Gross Alpha	1,3	$ 37.00

1. All new systems – quarterly for first year.
2. With Chemical Monitoring Sampling Waiver – test every three years.
3. Schedule based on initial monitoring.

Figure 4. Required water quality testing for community public water systems in New Hampshire (NH DES 2007c).

The other 4 PWSs that could serve as potential groundwater monitoring locations are non-transient/non-community wells. Although their testing requirements are fewer than community PWSs, they are also required to test for bacteria, nitrates, nitrites, lead, copper, IOCs, SOCs, and VOCs (NH DES 2007d). As mentioned previously, there are no state requirements for private well testing. However, for both the non-transient/non-community and private wells, cooperation with well owners, if carried out effectively, will be beneficial for all parties involved. Well owners will be able to monitor their drinking water quality over time and GMCG and watershed towns will be able to observe any changes in water quality for the most vulnerable section of the Ossipee Watershed. Because one of the limiting factors is the cost associated with testing for some of these chemicals, finding ways to share the burden among well owners, watershed towns, and GMCG would also facilitate monitoring efforts.

SUMMARY OF RECOMMENDATIONS

Groundwater is an important natural resource both globally and within the United States. In the Ossipee Watershed, groundwater is a significant source of drinking water that has the potential of being contaminated by certain land use practices. Identifying these PCSs and acknowledging their influence on groundwater and the Ossipee Aquifer will assist in determining the focus of drinking water protection. Planning and managing water resources in the Ossipee Watershed will help ensure that groundwater will always be an excellent source of drinking water. Based on analyses presented in this report, a summary of the recommendations follows.

General Education and Outreach Reccomendations

❖ Focus outreach and educational materials on assisting the three major types of PCSs found in the Ossipee Watershed: 1) vehicle service and repair shops, 2) aboveground and underground storage tanks, 3) fueling and maintenance of earth moving equipment.

- Provide information regarding where and how to properly dispose of used oil, antifreeze, and other motor vehicle fluids.
- Provide AST and UST owners with information on NH DES requirements and proper maintenance of these facilities.
- Provide educational materials for contractors and excavators regarding specific BMPs for these transient land use practices.

Specific PCSs for Education and Outreach

❖ Prioritize PCSs for BMP education and outreach efforts.

- Focus on 62 PCSs over primary aquifer recharge areas (Table 6, Appendix B).
- Focus on 29 PCSs within WHPAs of PWSs (Table 7, Appendix C).
- Focus on 8 PCSs within 250 foot (76 meter) buffer of surface water features (Table 9).
- Place highest priority on 17 PCSs that exist over primary aquifer recharge and are within WHPA boundaries (Table 10).

Provide Outreach and Education for Residents with Private Wells

❖ Assist residents with an understanding of the relationship between nearby land uses (PCSs) and the quality of drinking water in their private well.

❖ Encourage well testing recommendations provided by NH DES (Figure 3)

Groundwater Monitoring

❖ Initiate groundwater monitoring program by focusing on high vulnerability areas.

- Work with PWSs and private residents in this region and focus on testing for VOCs (Appendix E).

❖ To get a general sense of groundwater quality throughout the watershed, work with Community PWSs because they have the most comprehensive water testing requirements (Figure 4).

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Appendices

The tables found in Appendix A, B, C, and E have not been included in this copy of the Ossipee Watershed groundwater vulnerability report. If this information is desired please contact the Green Mountain Conservation Group or New Hampshire Department of Environmental Services.

Appendix A: Complete PCS List by Town

Appendix B: Ossipee Aquifer PCS List

Appendix C: PCSs Located Within WHPAs

Appendix D: GIS Analysis

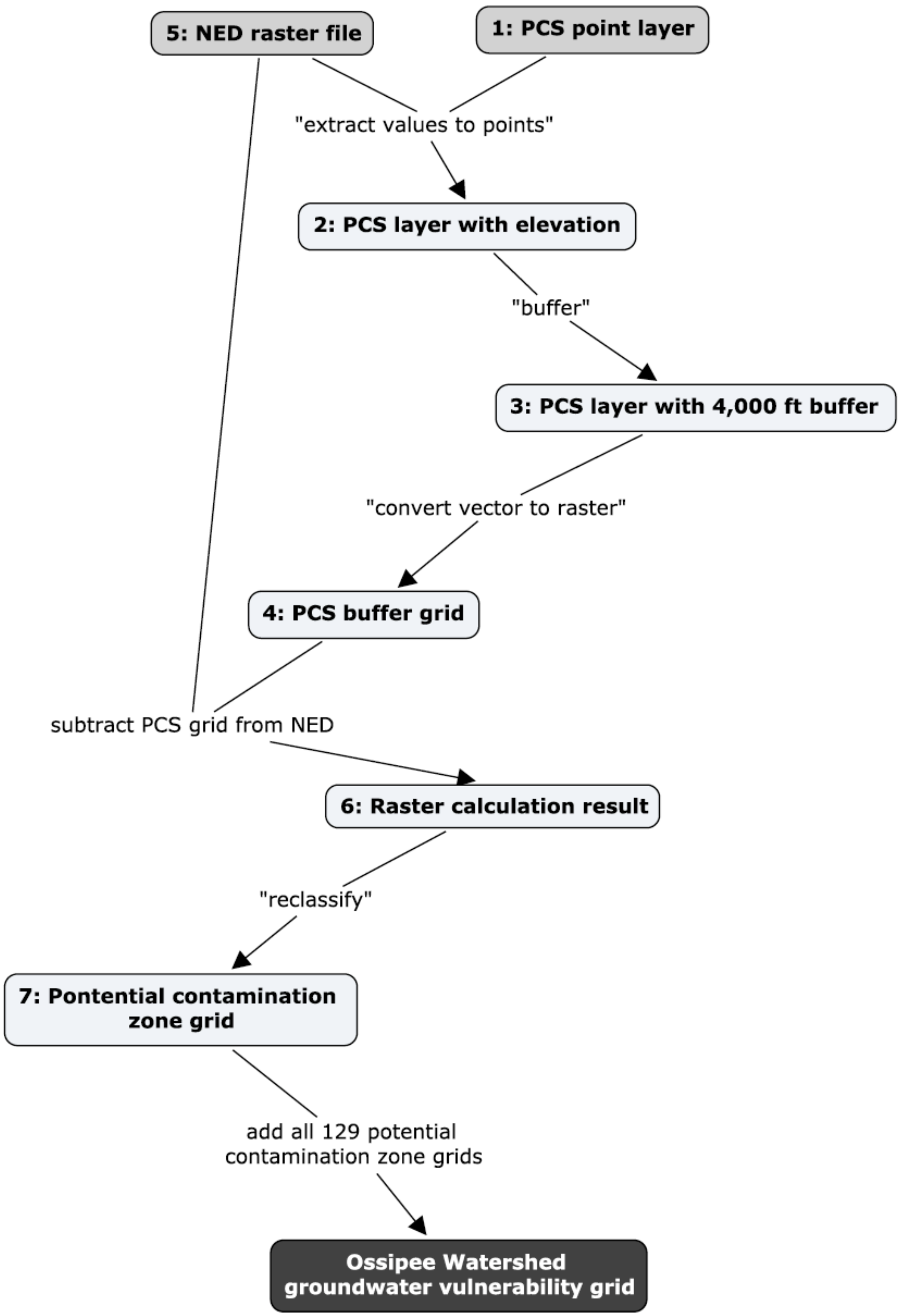
The GIS layers used in this report were obtained from various sources and are outlined in the table below:

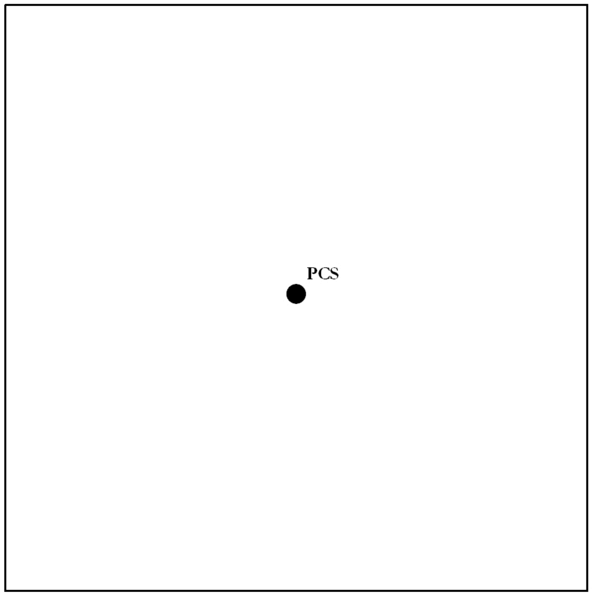
Data Source	GIS Layers
NH GRANIT (http://www.granit.unh.edu)	• Ossipee Watershed hydrology • NH political boundaries • NH public roads
NH DES	• PWSs • WHPAs • private wells
GMCG	• PCSs • Ossipee Watershed boundary • aquifer recharge areas
USGS Seamless Data Distribution System (http://seamless.usgs.gov/index.php)	• National Elevation Dataset (NED) file: 20 meter raster

Groundwater Vulnerability Analysis

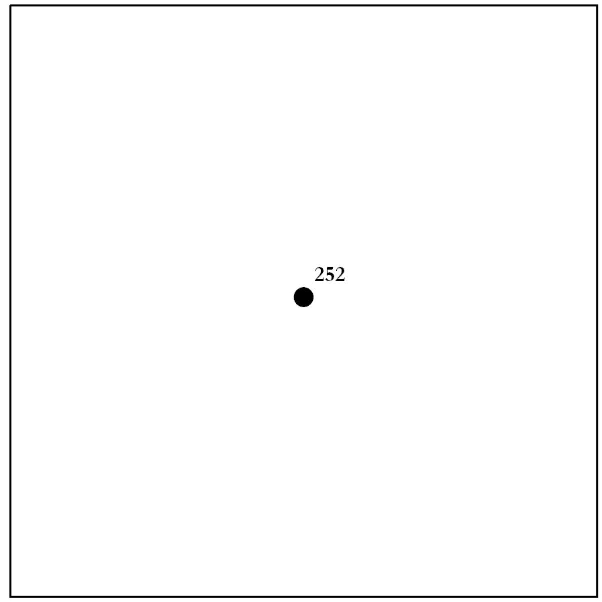
The first step in the vulnerability analysis was to link elevation values to the PCS points. This was achieved by using the GIS tool “extract values to points”. The single PCS file was separated into 129 files so that each PCS point was its own layer. Each file was then analyzed separately to determine the potential contamination zone. Using the “buffer” tool each PCS point was buffered by a circle with the radius of 4,000 feet. This vector file was then converted to raster with 20 meter by 20 meter cells in order to correspond with the NED file. Each pixel in the converted raster file for each PCS had the same elevation value. This grid was then subtracted from the original NED using the raster calculator. The resulting values were reclassified as follows: all cells with negative values were given a value of 1 and all cells with positive and “no value” were give a value of 0. The reclassified grid shows the potential contamination zone with those cells having a value of 1.

Once these calculations were completed for all 129 PCSs, the 129 potential contamination zones were added together through a raster calculation. This final raster file gave the groundwater vulnerability scores for the entire watershed.

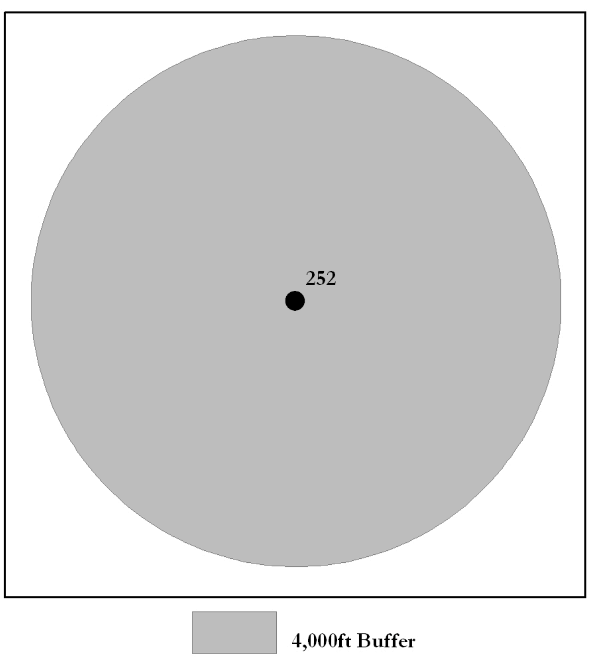

5: NED raster file
1: PCS point layer
"extract values to points"
2: PCS layer with elevation
"buffer"
3: PCS layer with 4,000 ft buffer
"convert vector to raster"
4: PCS buffer grid
subtract PCS grid from NED
6: Raster calculation result
"reclassify"
7: Pontential contamination zone grid
add all 129 potential contamination zone grids
Ossipee Watershed groundwater vulnerability grid



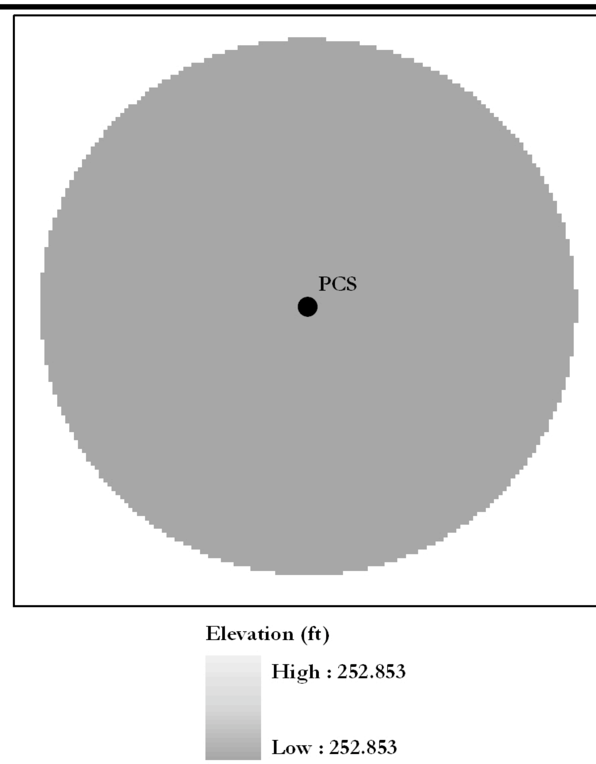
1: Original PCS point layer with one point to demonstrate the groundwater vulnerability analysis process.



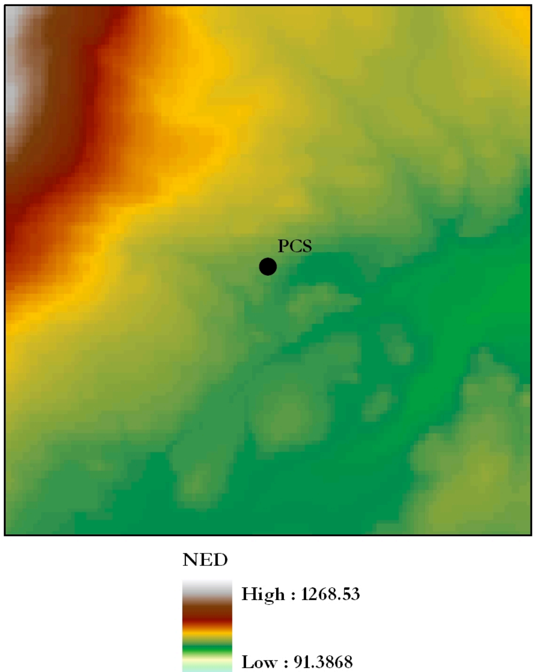
2: PCS point layer after the GIS tool, "extract values to points", has been used. The elevation value from the NED layer has been linked to the PCS point in the attribute table (252 feet).



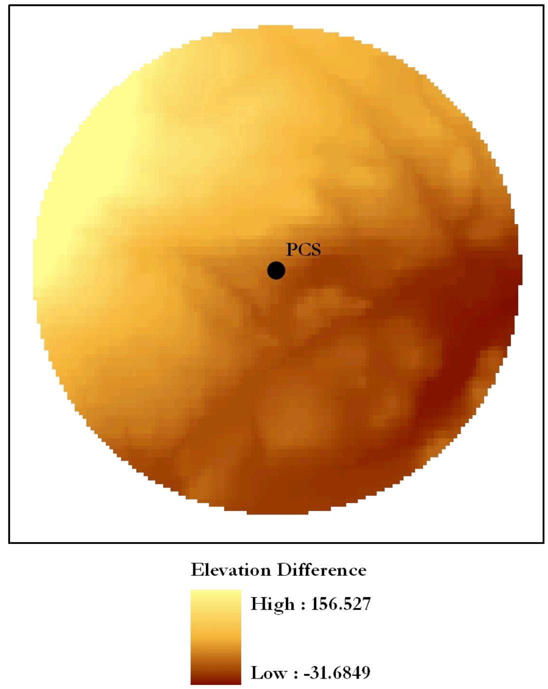
3: The "buffer" tool is used to create a 4,000 ft buffer around the PCS point. Because the elevation is linked to the PCS point, the elevation value is also linked to the polygon that is created from the buffer command.



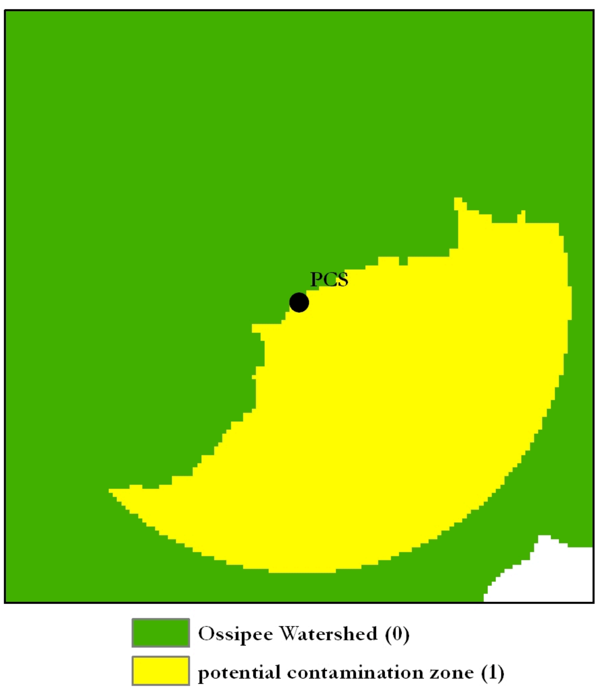
4: The polygon is converted to a raster file using elevation as the attribute for the conversion. As a result, all the pixels have the same value.



5: The NED layer showing elevation around the PCS point.



6: The results after the raster file in 4 is subtracted from the NED layer. Negative values are down-slope from the PCS point and positive values are up-slope.



7: The grid in 6 is reclassified so that all negative values have a value of 1 and all positive values have a value of 0. The pixels that have a value of 1 make up the potential contamination zone

Final Steps: This process is completed for all 129 PCSs and each has a layer similar to that in 7. The 129 layers are added together so that overlapping potential contamination zones result in a higher vulnerability score. In other words all the pixels with a value of 1 are combined. The final map shows vulnerability scores across the Ossipee Watershed (Map 7).

Appendix E: Potential Groundwater Monitoring Wells