MASTER'S PROJECT: PREPAREDNESS FOR OIL AND HAZARDOUS MATERIAL SPILLS IN THE LAKE CHAMPLAIN BASIN

MASTER'S PROJECT: PREPAREDNESS FOR OIL AND HAZARDOUS MATERIAL SPILLS IN THE LAKE CHAMPLAIN BASIN

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ABSTRACT

Lake Champlain faces numerous complex environmental threats that do not have simple solutions. Oil and other types of hazardous materials spills are among those threats that continue to attract the attention of agencies and organizations trusted to protect the lake. There is significant transportation infrastructure that exists in the region that, in the event of an accident, could lead to spills and extensive damage to natural resources. This project is intended to strengthen the ability of marina owners and first responders in the Lake Champlain Basin to prepare for and respond to oil and hazardous material spills by facilitating spill response training and providing important educational resources. The project is also intended to bolster federal, state and local spill planning efforts through development of the *Physical Description of the Lake,* which will serve as an appendix to the Multi- Agency Contingency Plan for Emergency Environmental Incidents in the Lake Champlain Region. Finally, the project is intended to increase awareness of available scientific information and expertise for spill response professionals through the development of a database of academic and scientific resources to support readiness for environmental incidents. The products generated for this project are intended to be useful for contingency planners, response personnel and resource managers engaged in spill response. The lake crosses international, federal and state jurisdictional boundaries which complicates preparedness and response in the event of a spill. This project is intended to help to unite the scientific and spill response communities in the Champlain Valley.

ACKNOWLEDGEMENTS

This project has provided me the opportunity to expand my knowledge on the science of oil spills in freshwater ecosystems and the complexities of the Lake Champlain Basin. I have truly appreciated the opportunity to return to Vermont and utilize my Coast Guard experience to make a difference in the local response community. I have learned many lessons and made new professional connections which I will take with me in my Coast Guard career.

I specifically want to thank Kristine Stepenuck for bringing me into her lab as a Graduate Student and for always being quick with an idea. I enjoy your enthusiasm for your work and appreciate your ability to manage a busy schedule. You always have a positive outlook and have encouraged me to expand my knowledge.

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CHAPTER 1: INTRODUCTION

Lake Champlain is one of the largest freshwater lakes in the United States and is classified as an inland waterway for purposes of federal jurisdiction (Weston Solutions Inc., 2013). It is a scenic and historic lake in northern Vermont, New York and southern Quebec that supplies drinking water for the region and is a treasured natural resource. It is unique in many ways including its massive basin area, significant depth, and five distinct but connected hydrographic segments. Lake Champlain currently faces several environmental challenges including non-point source pollution from stormwater, agricultural runoff and aquatic invasive species (Winslow, 2008). For a lake of its size it has been largely devoid of significant oil and hazardous material threats over the last few decades due to the absence of large vessel traffic and limited shoreside infrastructure. The one notable exception is railroads. Rail corridors run along the water on both the east and west shorelines of the lake (Figure 1). Railroads transport passengers and a variety of freight including hazardous materials like ethanol, fertilizers, bulk industrial chemicals and crude oil (Canadian Pacific Railway, 2020). During a peak period in 2014 unit trains carried 15-30 million gallons of volatile Bakken crude oil per week along Champlain Valley rail corridors, often within feet of the lake (Saxton, 2020). The demand for this crude oil is driven by fluctuating global oil prices, variable transportation costs and infrastructure capacity. New oil pipeline projects in Canada and the United States are being scrutinized by environmental activist groups which complicates the logistics to transport oil from production areas in the middle of the North American continent to the refineries on the east coast of the United States and Canada (Bourguet & Murphy, 2018).

Couple the steady demand for oil with aging rail infrastructure and climate change influencing weather patterns and a dangerous situation with extremely high consequences exists. If a derailment or another major spill were to occur the damage to Lake Champlain could be substantial.

Figure 1: A Canadian Pacific Railway unit train transports crude oil along the shores of Lake Champlain near Port Henry, NY. Photo Credit: Frank Jolin.

The current spill hazards on Lake Champlain include refined fuels used in boats and at shoreside facilities, truck and tanker traffic on nearby roads and bridges, and crude oil and hazardous materials transported on railroads. Spills in this region are statistically low probability but are high-risk events due to the slow recovery rates from spills in freshwater environments (Sergy & Owens, 2011). In cities where there is significant oil industry or commercial vessel traffic, resources to mitigate a spill are often plentiful, but in more remote or undeveloped areas, critical response resources may be hours away. This is the case in the Lake Champlain region where most equipment and personnel to mitigate a spill beyond first response are located in Albany, NY or Boston, MA (Weston Solutions Inc., 2013). Local response personnel have limited training and equipment and are likely to be quickly overwhelmed with a major spill into the lake. The risk to Lake Champlain for oil and hazardous material spills from the railroad has led to an increased need for preparedness in the region. Working with Lake Champlain Sea Grant and regulatory agencies, this project will educate local marinas and first responders, strengthen the existing Area Contingency Plan (ACP) and create a network of Scientific Support resources to help protect sensitive resources and aid in operational decision making.

1.1 Lake Champlain Oil and Hazardous Material Spills

The Lake Champlain region is not immune to oil and hazardous material spills. It has experienced numerous actual and near-miss incidents since the beginning of the industrial revolution and the increased use and transport of toxic substances as detailed in Table 1. Most of the earlier incidents are not documented partly because modern environmental regulations were not put in to place until the middle of the 20th century (e.g., Clean Water Act, Toxic Substances Control Act). Lake Champlain has at least 56 documented shipwrecks and numerous other submerged industrial remnants (Lake Champlain Maritime Museum, 2020). There are superfund hazardous waste sites located in the region including the Pine Street Barge Canal (coal tar) in Burlington, VT and the former Plattsburgh Air Force Base (volatile organic compounds) in Plattsburgh, NY (U.S. EPA, 2020). Highway accidents are another source of spills that threaten waterways. In the Unites States, there is an estimated 800,000 shipments of hazardous materials per day and an estimated 11% of all freight transported by trucks is a hazardous material (U.S. DOT, 2008). There are no reliable statistics for the Champlain Valley, but many rural areas rely on the road system to deliver heating oil and other refined fuels to homes, farms and smaller distributors. Vermont, New York and Quebec share important railroad corridors that carry freight and people between major economic hubs. The railroads in the Champlain Valley have had many derailments over the years. It is difficult to find detailed information on incidents, but in 2019 alone, Vermont reported five train incidents including three derailments, and New York reported 48 incidents and 19 derailments statewide. (Federal Railroad Administration Office of Safety Analysis , 2020). There are no comprehensive oil and hazardous material spill databases in the region. Information about spills must be pulled from old news articles, state websites, and other historical accounts. Table 1 shows the most well-documented oil and hazardous material spills that have affected or threatened Lake Champlain over the last 50 years. It is not a comprehensive list and there were likely many close calls not documented or examined in this project.

Table 1: A partial list of actual and potential oil and hazardous material spills into Lake Champlain.

Incident	Location	Date	Material Spilled	Details
Sinking of the Tug William H. McAllister	Schuyler Reef, NY	November 17, 1963	Unknown Quantity: Diesel Fuel	Tug ran aground and sunk in 140 ft of water. 14,000 gallons of Diesel potential (Winslow, 2010).
Storage Tank Overfill (Fuel Terminal)	Plattsburgh, NY	March 23, 1971	42,000 gallons: #6 fuel oil	Overfilled oil ran into a ditch leading to the lake. Most of the oil was trapped under ice where it was later recovered (US Environmental Protection Agency , 1992).
Train Derailment (Canadian Pacific)	Port Henry, NY	May, 1995	Cement; Sodium Chlorate	112 cars derailed. 2 cars carrying cement went into the lake through the ice (Lamoureux, 1995).
Train Derailment (Canadian Pacific)	Ticonderoga, NY	May 24, 2004	23,000 gallons: Canola Oil	5 cars derailed into the water. Unspecified amount entered the lake (Brotherhood of Locomotive Engineers and Trainmen, 2004).
Home Heating Oil Spill	Shelburne, VT	March 31, 2005	500 gallons: #2 fuel oil	Spill occurred in basement of residence. Oil made it to the lake via abandoned pipe. Oil in ice recovery required (Young, 2005).
Train Derailment (Canadian Pacific)	Essex, NY	May 26, 2007	None	12 of 33 cars derailed. Carrying methylene chloride & methyl bromide. Cars damaged but no chemicals released (Dedam, 2007).
Train Derailment (VT Railways/ Global Oil)	Middlebury, VT	November 22, 2007	1000 gallons: Gasoline	18 cars derailed. Gasoline discharged into Otter Creek, a major tributary of Lake Champlain. Evacuations made. Fires had to be extinguished (Bazenas, 2007).

Commercial and industrial vessel operations on the lake have decreased significantly over the last century, however a variety of transportation corridors continue to pose spill risks in the Lake Champlain Basin, including railroads, canal systems and highways (LCBP, 2020). This project intends to increase oil and hazardous material spill preparedness on Lake Champlain for spill response agencies and organizations. Chapter 2 contains the *Physical Description of the Lake* that was written to strengthen the existing Contingency Plan for Environmental Incidents in Lake Champlain (Weston Solutions Inc., 2013). Chapter 3 summarizes an oil spill workshop that was organized to provide spill preparation and response training to marina owners and first responders in the region. Chapter 4 describes the Scientific Support Network that was developed to identify resources from academic institutions that could provide valuable information and expertise to federal, state and local agencies during a spill. Finally, Chapter 5 offers suggestions for additional ways for federal and state planners to improve oil and hazardous materials spill preparedness in the region based on research and survey results.

CHAPTER 2: PHYSICAL DESCRIPTION OF LAKE CHAMPLAIN

2.1 Introduction

The impacts of an oil or hazardous material spill will be vastly different based on the nature of the incident, location of the spill and availability of resources. Contingency plans are developed to address specific geographic factors and provide a blueprint for the response to an environmental incident (U.S. EPA, 2018). Area Contingency plans are required for both coastal and inland zones by federal law in accordance with the National Response System ("The Oil Pollution Act of 1990"). The United States Coast Guard (USCG) is the lead agency for the Coastal Zone and the United States Environmental Protection Agency (EPA) is the lead for the Inland Zone. Lake Champlain falls in between two inland zones, with EPA Region 1 having jurisdiction over Vermont and Region 2 having jurisdiction over New York. The lake not only divides two state jurisdictions but creates an International border with Canada. Due to the importance of Lake Champlain and the multitude of overlapping authorities, it was decided that the lake would have its own multi-agency contingency plan (Weston Solutions Inc., 2013). The plan is designed to provide guidance on oil and hazardous material spill response. It includes contact information, notification requirements, response procedures, and other important resources. Contingency plans are the primary planning tools for government and industry stakeholders. They provide a backbone for local and industry response plans and inform response operations for specific geographic areas. The initial Lake Champlain Contingency Plan was promulgated by the Environmental Protection Agency, US Coast Guard, and the states of Vermont and New York in 2013 (Weston Solutions Inc., 2013). This plan is very new and still under development. EPA Region II On-Scene Coordinator Carl Pellegrino identified that the plan was lacking a physical description of the Lake Champlain Basin (C. Pellegrino, personal communication, November 30, 2018). The Clean Water Act specifies that Area Contingency Plans should include a section to "describe the area covered by the plan, including the areas of special economic or environmental importance that might be damaged by a discharge" (CWA § 311(j)(4)(C)(ii)).

After examining the EPA Region 10's Inland Area Contingency Plan section on Lake Washington, it was determined that the Lake Champlain plan lacked information critical to understanding how and where oil or other hazardous materials may move within the lake if a spill were to occur (Northwest Area Committee, 2014). The lake has unique features given its size and depth that are not fully understood by emergency responders. It is paramount they understand features of the lake including geology, hydrology and climate to effectively plan for and respond to oil and hazardous material spills. Contaminants will not likely be contained immediately, and, as such, responders will need to predict pollutant movement and employ mitigation measures based on existing conditions.

2.2 Methods

The information for the appendix to the contingency plan was collected using both qualitative and quantitative approaches to analyze existing data. The Geographic Area section was written by reviewing and compiling information from a variety of written and online resources. Resources on the Lake Champlain Basin Program website, *Lake Champlain A Natural History* (Winslow, 2008) and the *Limnology of Lake Champlain Report* (Meyer & Gruendling, 1979) were used extensively to compile the majority of background information on Lake Champlain, its structure, and its current use. There were some discrepancies in drinking water use between some of the references so the report on the economic value of clean water in the lake (Voigt, Lees, & Erickson, 2015) was used because it was peer reviewed and was one of the most recent publications about Lake Champlain and its use as a drinking water source.

The Hydrology section used a quantitative method to compile tributary flow and lake level data from the long-term monitoring program through the State of Vermont and United States Geological Survey stream gauge readings. Information on flooding, and the Richelieu River were taken from the draft report from the International Lake Champlain-Richelieu River Study Board which outlined the record flooding in the Richelieu River in the Spring of 2011 (International Lake Champlain - Richelieu River Study Board, 2019). The lake stratification, surface currents and seiche sections were thematic analyses completed by reviewing multiple reports on the hydrology of the lake. The *Limnology of Lake Champlain* report (Meyer & Gruendling, 1979) along with more modern studies conducted by a Middlebury College team (McCormick, Manley, Beletsky, Foley III, & Fahnenstiel, 2008) were used to describe these processes. The surface current map was made by using a NOAA navigational chart and overlaying arrows based on the reports listed above. Both hand drawn graphics and written descriptions were utilized to develop the figures.

The Climate section was developed mostly through quantitative analysis of existing data from the National Weather Service (NWS), recreational wind forecast applications and remote weather station data. The weather information was compiled to provide a general summary of the climate in the Champlain Valley, but numerous links were provided within the resulting document to allow first responders access to current conditions on the lake. The Ice Cover section provides a link to the NWS website where satellite photos of the ice coverage on the lake are posted regularly to show current conditions.

The Risk Assessment section was written using thematic analysis of many different sources of data. I performed key-word searches in Google using the terms oil spill, spill, and hazardous material spill for both Vermont and New York. I searched state regulatory websites from the State of Vermont (https://anrweb.vt.gov/DEC/ERT/Spills.aspx) and New York (http://www.dec.ny.gov/chemical/8437.html) to analyze past spill data. Descriptions of the lake from the Lake Champlain Basin Program website (LCBP, 2020) were used to identify current commercial and industrial uses in the basin. Websites for the New York (Canadian Pacific Railway, 2020) and Vermont (Vermont Rail System, 2020) railroad companies were used to confirm routes and cargos. The U.S. Coast Guard Station in Burlington, Vermont provided information on the commercial vessel operations (E. Green, personal communication Feb 21, 2020). Google Earth was used to identify and assess transportation infrastructure. The *Physical Description of the Lake* that was developed will be transferred to the U.S. EPA to be added to the Multi-Agency Contingency Plan for Emergency Environmental Incidents in the Lake Champlain Region (Weston Solutions Inc., 2013).

2.3 Results

MULTI-AGENCY CONTINGENCY PLAN FOR EMERGENCY ENVIRONMENTAL INCIDENTS IN THE LAKE CHAMPLAIN REGION

APPENDIX G: PHYSICAL DESCRIPTION OF THE LAKE

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1.0 INTRODUCTION

This appendix provides an overview of the physical features of Lake Champlain, its diverse watershed and the environmental risks associated with a spill of oil or hazardous materials. The area has a rich history from its geological and cultural origins to its role as a transportation highway and the many naval battles that have been fought upon its waters. Lake Champlain is one of the largest freshwater lakes in the United States and was designated as a resource of national significance in 1990 under the Lake Champlain Special Designation Act.[1] This act provides valuable funding and requires a higher level of protection and coordination from Federal and State governments. The special designation demonstrates the significant value of the lake as a natural, cultural, and recreational resource. Currently the lake faces many environmental challenges including urbanization, agricultural runoff and aquatic invasive species.[2] There are numerous research initiatives and restoration projects underway to better understand and mitigate the effects of these challenges. The following sections will provide an in-depth description of the physical features, hydrology and climate of Lake Champlain as they relate to environmental response operations.

2.0 GEOGRAPHIC AREA

Lake Champlain lies in the middle of the Champlain Valley between the Adirondack Mountains in New York and the Green Mountains of Vermont. It forms a boundary between the two states as well as an international border with the province of Quebec, Canada. The lake stretches 120 miles (193km) from Whitehall, NY at the Champlain Canal north to the outlet at the Richelieu River near Rouses Point, NY. It is 12 miles (19km) across at its widest point with an average depth of 64 feet (20m). The lake has an extensive drainage basin consisting of 11 distinct watersheds covering 8,234 square miles (21,325km^2).[3] This represents a 19:1 ratio of land to water surface area in the entirety of the basin. The massive size of the basin means the land surrounding the lake has a significant effect on the quality of the water in the lake because of natural and human activities. Lake Champlain has a long, narrow shape and can be divided into 5 distinct sections based on different physical, chemical and biological properties. The lake has shallow, eutrophic bays, deep cold-water troughs, and a narrow southern segment that behaves more like a river. There are many different shoreline types including protected sandy beaches, wetlands, manmade structures and exposed rocky cliffs.[2] The lake has over 70 islands, numerous protected bays and over 300 tributaries further adding to the complexity of this unique freshwater system.

2.1 Lake Champlain Statistics:

Table 1: Lake Champlain Physical Characteristics.[4]

Maximum Length:	120 miles / 193 kilometers
Maximum Width:	12 miles / 19 kilometers
Maximum Depth:	400 feet / 122 meters
Average Depth:	64 feet/ 20 meters
Surface Area (Water):	435 square miles / 1,127 square kilometers
Average Lake Level (Above Mean Sea Level):	95.5 feet / 29.1 meters
Maximum Measured Lake Level: (2011)	103.57 feet / 31.57 meters
Length of Shoreline:	587 miles / 945 kilometers
Number of Islands:	Greater than 70
Number of Beaches:	54 Public + 10 Private
Surface Area of Watershed:	8,234 square miles / 21,326 square kilometers
Typical Periods of Stratification:	May to October and during periods of ice cover

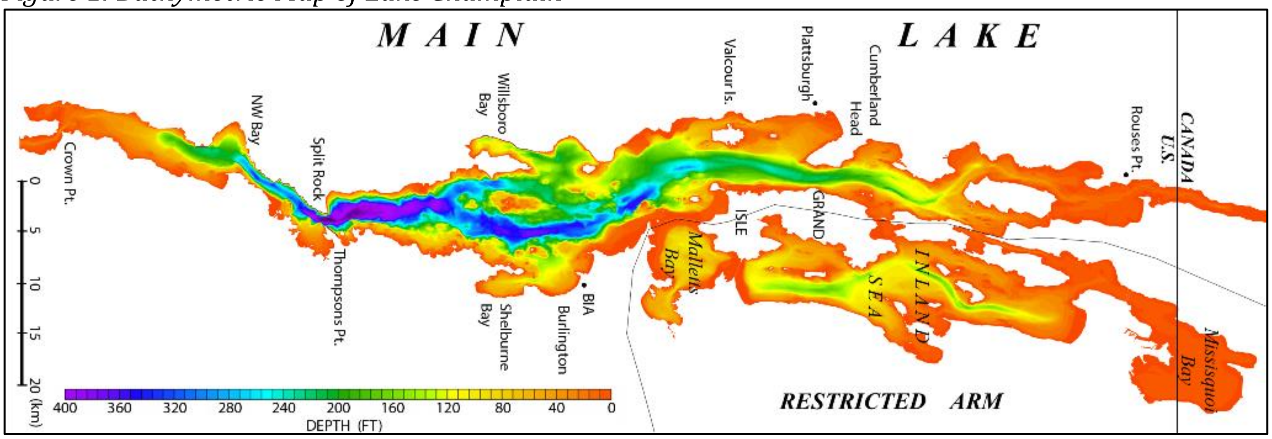
2.2 Geology and Origins:

The Champlain Valley has a rich geologic history. The Green Mountains were formed by a thrust fault around 450 million years ago.[5] The Adirondacks were formed 10 million years ago when ancient rocks were pushed upward in a dome-like formation. Although these two mountain ranges cradle the Champlain Valley for much of its length, it was the stretching of the continental crust that formed the lake's current basin. As two parallel faults stretched apart, a block of land between them dropped to form what is called a graben, which is now where the lake resides.[2] The valley was further sculpted by numerous ice sheets that occupied the area ending with the Laurentide Glaciers which reached their southernmost extent nearly 18,000 years ago. As the final glaciers melted and receded, Lake Vermont was formed which occupied an area much larger than the current lake and flowed south into the Hudson River. Around 12,000 years ago, the glaciers retreated enough to the north to allow the flow of freshwater north to the St Lawrence River. The land underneath the glaciers had been so depressed from the weight of the snow and ice that after the initial outflow of freshwater, the Atlantic Ocean soon flowed into the basin forming the brackish Champlain Sea which persisted for nearly 2,000 years.[2] After a brief period of being an inland sea, the land that was once under the ice sheets rebounded and the northerly flow of the lake was restored. The waters were then diluted back to freshwater from terrestrial runoff and snowmelt. The Lake Champlain Basin is widely studied for its unique and accessible geological features including ancient fossilized coral reefs and thrust fault formations.[5]

2.3 Lake Bathymetry:

Lake Champlain has many unique bathymetric features which influence water and sediment movement, ice formation and weather conditions throughout the basin. Figure 1 is a bathymetric map created by Middlebury College to easily depict the deeper areas of the lake.

Figure 1: Bathymetric Map of Lake Champlain



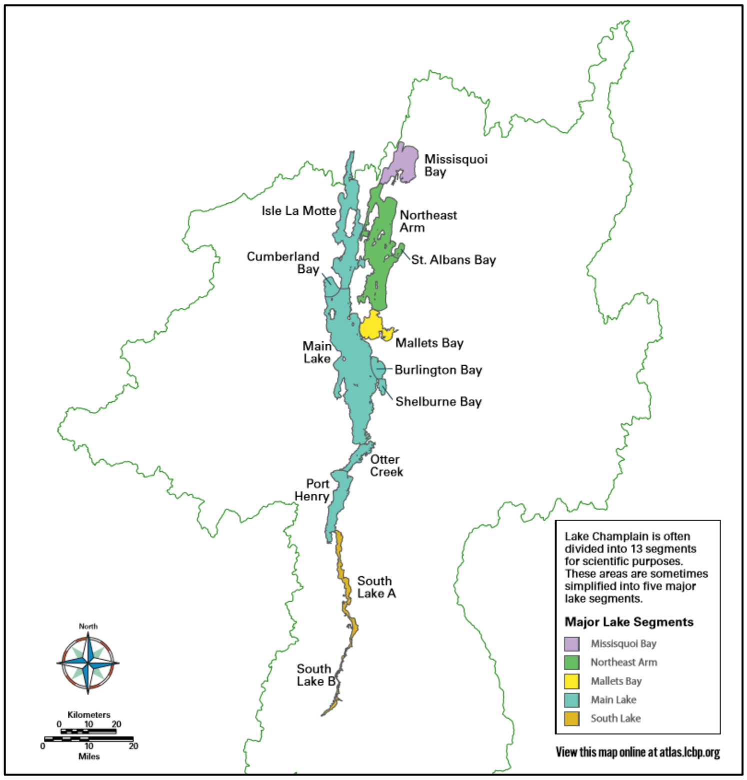
The National Oceanic and Atmospheric Administration (NOAA) developed navigational charts for Lake Champlain and are available at https://www.charts.noaa.gov. These charts along with electronic charts are periodically updated and represent the most current bathymetric data for navigational use on Lake Champlain. Each of the following charts is hyperlinked to its online source:

- Chart # 14781 Riviere Richelieu to South Hero Island
- Chart # 14782 Cumberland Head to Four Brothers Islands
- Chart # 14783 Four Brothers Islands to Barber Point
- Chart # 14784 Barber Point to Whitehall
- Chart # 14785 Burlington Harbor

2.4 Five Distinct Sections of Lake:

Lake Champlain can be divided into five distinct sections based on their unique physical, chemical and biological characteristics. Some of the sections have limited hydrological connection to the rest of the lake and are sometimes treated as separate waterbodies. The characteristics of each section will have an effect on the fate of an oil or hazardous material spill and should be considered when planning for response operations. Figure 2 shows the five distinct sections, and a detailed description of each, moving from north to south.[3] For a more detailed map of the lake and its named features, access the links above in Section 2.4 to view the NOAA Navigational Charts

Figure 2: The Five Distinct Sections of Lake Champlain



- <u>Missisquoi Bay:</u>

This large, shallow bay extends northeast from the Alburgh/Swanton bridge and includes an international border (NOAA Chart # 14781). The majority of Missisquoi Bay lies in Quebec and has an average depth of approximately 14 feet (4m). It has three major tributaries that feed it including the Missisquoi River which has the largest influence on the water quality in this section. The shallow water in the bay is typically warmer than other areas of the lake and is murky due to runoff from the surrounding drainage basin and constant mixing. The bay forms ideal habitat for fish and wildlife due to the warmer water and significant wetland areas including the 6,729-acre Missisquoi National Wildlife Refuge. In the summertime, the bay experiences cyanobacteria blooms due to high nutrient loading from agricultural runoff. The water from this bay circulates counterclockwise and flows south into the Northeast Arm under most conditions.[2,4]

Response Considerations: The majority of Missisquoi bay is in Canada and the international border may present challenges in deploying response personnel and equipment during a trans-border response. The bay is shallow and is home to extensive wetlands and other important habitat that may restrict some response operations. The currents in the bay generally flow in a counterclockwise direction and exit to the south through the Alburgh/Swanton Bridge. This bridge and its channel could be a control point to prevent pollutants from entering or exiting Missisquoi Bay.

- Northeast Arm:

The Northeast Arm is also known as the Inland Sea and stretches from the Sandbar Causeway near South Hero, north to the Alburgh/Swanton bridge including the Alburgh Passage, Carry Bay and The Gut (NOAA Chart #14781). It is bordered by Grand Isle and North Hero Island to the west and mainland Vermont to the east. It has an average depth of 42 feet (13m) and is very isolated from the rest of the lake. There are no major tributaries in this section which often causes it to have higher overall water quality and less turbidity.[2] Water from this section flows in from Missisquoi Bay and Malletts Bay and exits into the Main Lake through narrow openings at The Gut and Carry Bay. St. Albans Bay and Maquam Bay are shallow and experience eutrophic conditions including harmful algae blooms and oxygen deficiency.

Response Considerations: The Northeast Arm is mostly isolated from all other sections of the lake. It is only connected through narrow openings through causeways and bridges. Depending on the lake level, wind direction and other hydrologic conditions the water at each of these narrow openings can flow in either direction so it is important to understand relevant conditions at the time of a spill. There are no major tributaries and very few sources for oil or hazardous material spills.

- Malletts Bay:

Malletts Bay is divided into the Inner and Outer Malletts Bay (NOAA Chart 17482). This is a popular boating and recreation area due to its protection from the winds on the main lake. It is formed by manmade causeways to the north at Sandbar State Park and to the west by the Colchester causeway, an old railroad crossing. The Lamoille River, a major tributary, enters the Outer Bay south of the Sandbar Causeway. This area hosts the Sandbar Wildlife Management Area (WMA) with Class 1 wetlands and over 1200 acres of protected habitat.[8] The Inner bay is separated by two rocky outcroppings that create a pinch point between Malletts Head and Red Rock Point. The inner bay is especially popular for sailing and other watersports. This section has some shallow areas but has a maximum depth of 105 feet (32m) and a higher water volume which increases the dilution of various nutrients and decreases the occurrence harmful algal blooms.[2,7]

Response Considerations: Malletts Bay is another very isolated section of the lake that is only connected to other sections through three narrow openings in causeways. It could be completely isolated with containment boom at the openings. There is a large recreational boating and watersport community in this section that would be heavily affected if there were a spill. The Class 1 wetlands at the Sandbar WMA are a priority for protection from a spill. With no major industry in this section, recreational boats pose largest threat for a spill. Malletts Bay will freeze over before the Main Lake.

- Main Lake:

The Main Lake covers over 300 square miles (777 km^2) and contains the majority of the lake's surface area and water volume.[4] It includes the deepest part of the lake near Thompsons Point (NOAA Chart # 17483) at 400 feet (122 m) deep.[2] The Main Lake begins at the Crown Point Bridge (NOAA Chart # 14784) and includes a continuous stretch of water on the west side of Grand Isle up to the Richelieu River outlet and the Canadian border(NOAA Chart # 17481). It is a popular area for recreation including boating and fishing and provides clean drinking water for numerous public water intakes. There are 14 major tributaries in this section including the Lamoille River and Otter Creek in Vermont, and most of the rivers draining the Adirondack region in New York State which are identified in Table 3 below. The Main Lake has a valuable cold-water fishery for lake trout and landlocked Atlantic salmon. The two most populous cities in the basin, Burlington, VT (42,260 in 2016) and Plattsburgh, NY (19,780 in 2016) are situated along the shores of the Main Lake.

Response Considerations: The Main Lake is by far the largest section of the lake. It also has the majority of the oil and hazardous material threats in the region. This large section is oriented north/south and seasonal winds can build up significant waves and surface currents due to its large fetch. Conditions on the main lake can often be more like the Great Lakes or an ocean and complex hydrological characteristics can challenge response operations. This section often does not freeze completely due to its size and depth. It does experience periods of strong stratification mainly during the summer months which can influence surface current patterns. The railroad tracks running down the western side of the Main Lake are the biggest threat for a large spill into the lake. Most of the Commercial vessels on the lake operate in this section. The lake only has one outlet at the Northern end of the Main Lake in Rouses Point. Here, the Richelieu River marks another international border and also the only way to regulate the lake level during flooding conditions.

- South Lake:

The South Lake is a 30 mile (48km) section that has an average width of 2/3 of a mile (1 km) and behaves more like a river.[8] It begins at the final lock on the Champlain Canal in Whitehall, NY (NOAA Chart # 17484) and flows north until it transitions into the Main Lake at the Crown Point Bridge. This section has three major tributaries, the Poultney, Mettowee and LaChute Rivers, the last of which drains from Lake George. The water in the South Lake averages 8.8 feet (2.7m) and this section is known for its warm water fishing. [2] The South Lake has issues with invasive species like zebra mussels, water chestnut and others that have been transported through the Champlain Canal, which enters the South Lake at Whitehall, NY.[8] The South Lake does not usually experience strong summer stratification.

Response Considerations: The South Lake is more like a river due to its distinct northerly flow, shallow depth and narrow width. Fast water spill techniques may be required depending on conditions. It would be easier to respond to a spill in this section because it is geographically closer to resources in Albany, NY. The consistent currents and narrow width make it easy to predict how the oil or hazardous material is going to move. The railroad runs along most of this section on the western side of the lake in New York. The Champlain Canal at the southern end could be used to bring spill resources into Lake Champlain from Albany and the Hudson River.

2.5 Historic and Current Use of the Area:

Lake Champlain has a long history of human use dating back more than 10,000 years to native populations who relied on the lake for food, water, transport and trade.[2] The valley alongside the lake was settled by Europeans because of its productive farmland and easy access to reliable trade routes up and down the lake. Following European colonization, the lake developed a significant military history and hosted important naval battles during the American Revolution and the War of 1812.[5] At one time it was substantial transportation corridor for goods transiting between Canada and New York City. Although the waterway remains open for business, commercial trade on the lake is largely a thing of the past. Now, Lake Champlain generates over $300 million dollars a year in tourism in Vermont alone.[8] It continues to be an important natural resource to northern Vermont, New York and Quebec, supporting agriculture and generating significant revenue from year-round recreation and tourism. In 2018, Lake Champlain was ranked as one of the eight premier freshwater boating destinations in the United States by BoatUS magazine.[8] It remains popular among recreational boaters, SCUBA divers, kite surfers, kayakers and many other water sport users. The lake supports multi-sport recreational paths along its shores and is a vital part of many paddler trails traversing the northern U.S. and southern Canada.[8] Numerous summer camps and educational programs use the lake as a classroom teaching research methods and environmental conservation principles.[6]

Fishing is an important economic draw that places great importance on healthy habitats and clean water. Fishing on Lake Champlain is responsible for approximately $205 million dollars in economic benefit per year.[8] The lake is home to more than 80 species of fish including many sportfish that draw anglers from all over the country.[8] Several species are actively stocked to help support populations including lake trout, Atlantic salmon and others.[3] There are dozens of fishing tournaments throughout the summer months and a substantial ice fishing community in the winter.

2.6 Industry and Infrastructure on the lake:

Industry on the lake and along its shorelines is limited. The primary infrastructure that may be affected during a spill of oil or hazardous materials on the lake is drinking water intakes and the transportation sector. Other infrastructure on the lake include 98 wastewater treatment plants[3], and the International Paper Mill in Ticonderoga, NY.

2.6.1 Drinking water:

More than 145,000 people rely on the lake for clean drinking water. There are approximately 100 public water suppliers and over 4,000 seasonal residences that draw over 20 million gallons (75 million liters) of water a day from various locations around the lake. In 2015, the Champlain Water District in Vermont won an award for the best tasting water in North America.[8] In Vermont, public drinking water intakes are identified on GIS maps available on the Agency of Natural Resources (ANR) website: http://anrmaps.vermont.gov/websites/anra5/. In New York, the intakes are available from the County Departments of Health. In Quebec, the Minister of Sustainable Development, Environment and Parks is responsible for public drinking water.

2.6.2 Transportation:

Lake Champlain hosts two ferry companies that operate four transport routes across the lake (Table 2). The Lake Champlain Transportation Company operates nine passenger and vehicle ferries at three different crossing points on the lake. The ferries are operated by diesel engines and are a prominent feature on the lake in the summer months. The Charlotte and Burlington ferries run seasonally, dependent on weather and ice conditions while the Grand Isle Ferry operates 24 hours a day all year long (https://ferries.com/). There is a smaller privately-owned ferry in the southern part of the lake. This Ticonderoga Ferry is a barge style vessel that utilizes a cable system to transit the ½ mile (0.8km) crossing from Shoreham, VT to Ticonderoga, NY (http://www.forttiferry.com/). The ferry system is an important transportation option for tourists, bikers and residents, many of whom use it to commute to their jobs. While the ferries may be impacted by a spill, they could also serve an important purpose during a response to an oil or hazardous material incident. For instance, they could transport equipment and personnel around the lake or carry large capacity storage tanks for removal operations.

Table 2: Lake Champlain Ferry System.

Route	Distance/Time	Operation	Propulsion
Grand Isle, VT to Plattsburgh, NY	2 miles/ 15 minutes	Year Round	Diesel
Burlington, VT to Port Kent, NY	10 miles/ 60 minutes	Seasonal	Diesel
Charlotte, VT to Essex, NY	3 miles/ 25 minutes	Seasonal	Diesel
Shoreham, VT to Ticonderoga, NY	0.5 miles/ 7 minutes	May - October	Cable

The Lake Champlain Basin is also home to a significant network of roads and highway systems that are adjacent to the lake or cross one of the hundreds of tributaries leading to the lake. There are eight bridges crossing portions of the lake. Route 22 crosses the southernmost section of the lake near Whitehall, NY. The Crown Point Bridge near the middle of the lake is the largest span connecting Crown Point, NY and Chimney Point, VT. Route 2 winds through the islands in the northern section of the lake. It crosses the lake in Colchester connecting mainland Vermont to Grand Isle and crosses two more times in the Northeast Arm before finally crossing the Main Lake to Rouses Point, NY near the Canadian border. There is a bridge crossing from Alburgh to Swanton, VT which is the boundary between Missisquoi Bay and the Northeast Arm. Lastly, there is a bridge crossing from South Alburgh to Isle La Motte. The bridges are all marked on standard driving maps and the NOAA navigational charts linked in Section 2.4.

Railroads were built along the lake starting in the mid 1800's. One connected Burlington to Boston and the other ran along the shores of the lake in New York, connecting Montreal and Albany. Railroads supported developing industrial and commercial enterprises and largely replaced the need for barge and steamship traffic on the lake.[5] Currently the Canadian Pacific Railway operates the rail line in New York that runs along nearly 100 miles (161 km) of the Lake Champlain shoreline – sometimes within feet of the lake – and then continues to follow the Champlain Canal on its way south. In Vermont, the New England Central Railroad crosses over the lake near the Alburgh/Swanton bridge and then heads inland on its way from Montreal to White River Junction. The Vermont Railway begins in Burlington and runs alongside the lake through Shelburne before heading inland on its way south to Rutland. From Rutland, the line heads to Whitehall, New York crossing the Champlain Canal twice.

3.0 HYDROLOGY

The hydrology of Lake Champlain is very dynamic and is significantly influenced by the massive basin that supplies its water. There are 11 distinct watersheds that drain into the lake. Collectively, these watersheds include hundreds of tributaries that drain to and through the Champlain Valley.[3] A detailed map of the Lake Champlin Watershed is available in the Lake Champlain Basin Program's atlas: https://atlas.lcbp.org/wp-content/uploads/2018/04/Basin_Poster_2016.png. The temperature, quantity and quality of the freshwater draining to the lake dictate currents, lake levels and water quality parameters. It is important to look at the watershed to understand the forces that influence these important characteristics of the lake. The fate and effects of oil and hazardous materials will be influenced by the hydrological forces in the basin.

3.1 Tributaries:

There are over 300 tributaries that empty into Lake Champlain (Tables 3,4 and 5).[7] Tributaries are critical factors in controlling the water quality of any lake. They influence the lake level, convey sand and sediments, provide critical habitat, and transport massive amounts of stormwater and runoff from across the landscape. Tributaries affect chemical, physical and biological processes in Lake Champlain. On Lake Champlain, such processes are closely monitored through the USGS WaterWatch system and the Lake Champlain Long-Term Monitoring Program. The USGS data are available in real time and are important for predicting surface current flows and other water quality parameters. The Long-Term Monitoring Project complements the USGS Stream gauges and reports data on numerous water quality parameters.

- Vermont Streamflow Data: https://waterwatch.usgs.gov/?m=real&r=vt
- New York Streamflow Data: https://waterwatch.usgs.gov/index.php?r=ny&m=real

- Quebec Streamflow Data: http://www.cehq.gouv.qc.ca/suivihydro/ListeStation.asp?regionhydro=03&Tri=Non
- Long-Term Monitoring Program Data – Tributary Monitoring Data https://anrweb.vermont.gov/dec/_dec/LongTermMonitoringTributary.aspx

Below is a list of the major tributaries of Lake Champlain. Drainage area and mean flow rates from the USGS Waterwatch and Quebec Hydrographic Region's websites are listed to show their overall effect on waterflow within the lake:

Table 3: Major New York Tributaries to Lake Champlain.

River Name	Main Stem Length	Drainage Area	Mean Flow	Point of Entry into Lake Champlain
Great Chazy River	43 mi (70km)	299 mi^2/ 774 km^2	244 ft^3/s 6.9 m^3/s	Champlain, NY; King Bay.
Little Chazy River	20 mi (32km)	53 mi^2/ 137 km^2	32 ft^3/s 0.9 m^3/s	Chazy, NY; North of Chazy Landing
Saranac River	56 mi (90km)	614 mi^2/ 1,590 km^2	715 ft^3/s 20.2 m^3/s	Plattsburgh, NY; Cumberland Bay.
Salmon River	13 mi (21km)	68 mi^2/ 176 km^2	43 ft^3/s 1.2 m^3/s	Plattsburgh, NY; South of Airport.
Little Ausable River	27 mi (43 km)	73 mi^2/ 189 km^2	36 ft^3/s 1.0 m^3/s	Peru, NY; North of Ausable Pt.
Ausable River	20 mi (32km)	513 mi^2/ 1,329 km^2	441 ft^3/s 12.4 m^3/s	Ausable, NY; North of Port Kent, NY.
Bouquet River	50 mi (80km)	272 mi^2/704 km^2	220 ft^3/s 6.2 m^3/s	Willsboro, NY; South of Willsboro Bay.
Putnam Creek	9 mi (14km)	62 mi^2/ 161 km^2	82 ft^3/s 2.3 m^3/s	Crown Point, NY; Gilligans Bay.
Mettawee River	41 mi (66km)	424 mi^2/ 1,098 km^2	274 ft^3/s 7.8 m^3/s	Whitehall, NY; Feeds Champlain Canal.

Table 4: Major Vermont Tributaries to Lake Champlain.

River Name	Main Stem Length	Drainage Area	Mean Flow	Point of Entry into Lake Champlain
Missisquoi River	96 mi (154km)	865 mi^2/ 2,240 km^2	1270 ft^3/s 36.0 m^3/s	Highgate, VT; North of Alburgh Passage.
Lamoille River	85 mi (137km)	723 mi^2/ 1,873 km^2	952 ft^3/s 27.0 m^3/s	Milton, VT; South of Sandbar Causeway
Winooski River	88 mi (142km)	1,063 mi^2/ 2,753 km^2	1460 ft^3/s 41.3 m^3/s	Burlington, VT; South of Colchester Point
LaPlatte River	18 mi (29km)	53 mi^2/ 137 km^2	31 ft^3/s 0.9 m^3/s	Shelburne, VT; Shelburne Bay
Lewis Creek	29 mi (46 km)	81 mi^2/ 210 km^2	85 ft^3/s 2.4 m^3/s	Ferrisburgh, VT; Hawkins Bay
Little Otter Creek	19 mi (31 km)	73 mi^2/ 189 km^2	51 ft^3/s 1.4 m^3/s	Ferrisburgh, VT; Hawkins Bay
Otter Creek	102 mi (163km)	944 mi^2/ 2,445 km^2	1010 ft^3/s 28.6 m^3/s	Ferrisburgh, VT; South of Thompsons Point.
Poultney River	29 mi (46km)	263 mi^2/ 681 km^2	325 ft^3/s 9.2 m^3/s	West Haven, VT; North of Whitehall, NY.

Table 5: Major Quebec Tributaries to Lake Champlain.

River Name	Main Stem Length	Drainage Area	Mean Flow	Point of Entry into Lake Champlain
Riviére Aux Brochets/ Pike River	42 mi (67km)	373 mi^2/ 966 km^2	58 ft^3/s 1.6 m^3/s	Saint-Armand, QC; Missisquoi Bay.

3.2 Richelieu River Outflow:

The Richelieu River marks the northern terminus of Lake Champlain near Rouses Point, NY and is the only outlet for the basin. The river flows 78 miles (125 km) north to Sorel-Tracy, Quebec, where it meets the Saint Lawrence River.[9] The lake level in Lake Champlain is directly governed by the flowrate through the Richelieu River. For the first 23 miles (37 km), the river only drops 1 foot in gradient, creating a very slow-moving channel. Near Saint-Jean-Sur-Richelieu, Quebec, the river narrows and drops 82 feet (25 meters) over 7.5 miles (12 kilometers). In order to facilitate vessel traffic through the rapids, the Chambly Canal was constructed in 1843 and consists of 9 locks allowing passage from the Saint Lawrence River to Lake Champlain. Below the Chambly Canal, the water level is controlled by a dam in Saint-Ours, Québec but it is not designed for flood control. There is currently no flood control infrastructure for the Richelieu River or Lake Champlain.[9] A spill of oil or hazardous materials on the lake could allow pollutants to be transported through the Richelieu River impacting important habitat, agricultural, and residential areas.

3.3 Champlain Canal and locks:

At the southern end of the lake, the Champlain Canal connects to the Hudson River. The 63-mile (101 km) canal begins in Fort Edward, NY, just east of Glens Falls and ends in Whitehall, NY, in the South Bay of Lake Champlain. It was constructed in 1823 as a branch of the Erie Canal to facilitate commerce in New York State. It was constructed as a barge canal and was used extensively throughout the 19th and 20th centuries to transport people and goods.[10] Although commercial transport through the canal has been reduced to almost nothing, it is still operable and could be an asset for transporting spill response vessels and equipment. It is maintained to minimum depth of 12 feet and the lowest overhead clearance is 17 feet. More information on canal operations can be found at: http://www.canals.ny.gov/wwwapps/navinfo/navinfo.aspx?waterway=champlain.

3.4 Dams in the Basin:

There are both hydroelectric and flood control dams on various tributaries in the Lake Champlain Basin. Most hydroelectric dams have little or no storage capacity and do not influence river flow rates.[11] Flood control dams were built in specific areas in response to major flooding events and were designed to protect downstream communities. Releases from flood control dams have a minor effect on the overall level of the lake at any given time because the volume of Lake Champlain is so large.[11] Lake George is the largest tributary lake draining into Lake Champlain and its flood control dam on the LaChute river is mainly used to regulate levels for recreational purposes.

3.5 Lake stratification:

In many large freshwater systems temperature gradients form during certain times of year. The difference in temperature between the surface layer (epilimnion) and the bottom layer (hypolimnion) leads to density differences in the water layers which act as barriers to pollutants, plankton and other dissolved substances. The temperature and density gradient is called stratification and it has a significant effect on the overall hydrology of a lake. Lake Champlain is a dimictic lake, meaning that parts of it experience two distinct periods of stratification and mixing per year.[2] Stratification does not occur in the entire lake. Shallower areas may remain isothermal (uniform in temperature) in the summertime and will fully mix. In deeper areas of Lake Champlain, stratification occurs in the summer (typically May through October) as the surface water warms and the dense cold-water sinks and, in the winter, when colder water and ice sit on top of warmer water below.[2]

During periods of stratification, currents may be enhanced in surface waters because of the reduced vertical mixing and separation of the surface currents from bottom friction.[12] It means that pollutants may spread faster over a larger area but only in the upper most layer of water column. Stratification also supports the formation of surface and internal seiche waves that occur because of the thermal and density layers. This phenomenon is discussed in section 3.6.

Periods of mixing mean the entire water column is able to homogenize and it has a relatively uniform temperature from the surface to the bottom. Nutrients, sediments and biota are able to move throughout the entire water column. For pollutant transport, at such times, any dissolution or diffusion of a specific substance can affect the entire water column down to the sediment.[12]

Thermal stratification is not a common water quality parameter reported by buoys or weather stations, but the Lake Champlain Long-Term Monitoring Project collects Multi-Probe Sonde data that tracks water temperature with depth. These data can be used to determine the current conditions in specific parts of the lake. Current and historical thermal profile data are available at: https://anrweb.vt.gov/DEC/_DEC/MultiProbeSonde.aspx.

3.6 Surface and Internal Seiche:

One unique phenomenon to be aware of on Lake Champlain is the wind-driven seiche. The lake has a long and narrow shape and is mostly oriented in a north/south direction. After longer periods of strong north or south winds, the surface water piles up at one end of the lake. The lake level rise is based on the velocity and duration of the wind but can usually be measured in inches. At times it has been observed that the seiche could reach a foot or higher based on wind conditions.[2] Once the prevailing wind reduces in speed, the water that had been pushed up releases and creates a sloshing effect in the basin. The resulting wave period can last for several hours.[13] The most observable effect is a rise in lake level at one end, but the seiche can reverse current flows through the most constricted areas of the lake like the Colchester Causeway and the Gut. This can be seen in Figures 3 and 4 marked with the red arrows. The effects of the surface seiche will only be noticeable in water less than 15 feet in depth like nearshore areas and shallow bays. The seiche occurs during the period of stable stratification typical in the summer and early fall because of the stronger density gradients in the water column.[13] The surface seiche, or wind tide, can influence surface flow and currents, which may move pollutants in the water in a direction opposite of the wind or predicted flow.

As the surface seiche pushes the surface water up on one end of the lake, the epilimnion, or upper layer of warmer, less dense water, subsequently pushes down in the water column. This creates a deeper warm water layer at the end of the lake where the wind is pushing and a shallower warm layer at the opposite end. Like the surface seiche, as the wind eases, an internal seiche is formed that will slosh back and forth in the basin for a period of around 4 days. These oscillations in the thermocline continue during most of the stratified summer period.[2] Although the internal seiche only affects the deeper parts of the lake where the density difference in the water is more pronounced, it can increase currents and transport water particles a significant distance. "A water parcel will be transported up and down the lake basin by the 4-day oscillation and will carry with it any dissolved materials or particulate matter it contains". [13 p. 18,427]

3.7 Surface Currents:

The mass transport in Lake Champlain reflects a mean surface water current of 10cm/s (0.23mph or 0.36kph) to the North.[14] The mass transport describes the long-term average movement of surface waters. This calculation does not account for the multitude of short-term variations present including prevailing winds, gyre circulation, internal seiche (discussed above), tributary outflow, shoreline features and coastal jets. Though relatively limited, studies of surface currents on the lake indicate that wind direction and intensity are the primary drivers of surface water movement.[14] The surface currents generally follow the prevailing wind direction and can be predicted using a progressive vector diagram (PVD) using 3% of the wind magnitude.[14] There are observed eddies and gyres present in the lake that can alter the surface transport of pollutants. Given the complex structure and morphology of the lake it is safe to assume there will be many localized variations to average flow expectations. It is best to consult with a physical oceanographer or physical limnologist to understand wind driven current mechanisms in more detail.

General Surface flow observations are detailed in Figures 3 and 4.[7] The black arrows indicate generally observed surface currents in the lake. The red bi-directional arrows indicate narrow openings between major basins in the lake. The surface currents in these constricted areas have been observed to flow in both directions dependent on wind direction, seiche movement and lake water levels. It is important to note that these charts were created from limited studies in summer months with a south wind. [7,14] These currents are typical for the lake, but wind direction and velocity are the largest factors affecting surface currents. Shoreline features, tributary inputs, seiche oscillations and stratification also influence surface currents and must be considered when predicting surface currents. The South Lake portion is not depicted on a chart because it generally flows in a northerly direction due to tributary inputs and its shallow and narrow shape. The northern sections are more complicated due to depth, hydrology and relative isolation from the rest of the lake.

Figure 3: Northern Lake Surface Currents

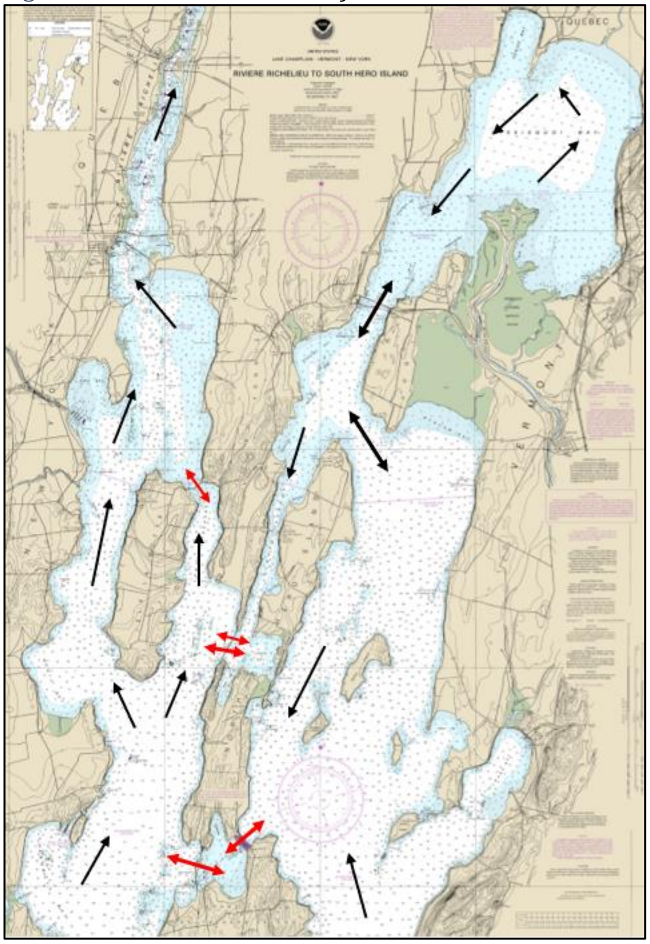


Figure 3 displays surface currents in the northern sections of Lake Champlain. The arrows do not reflect the velocity of the surface currents, only typical flow patterns.

The red, double-ended arrows represent narrow openings where the currents are known to shift direction based on wind and water levels.

The black arrows display average surface current movement in the given area.

Wind is the largest factor affecting surface currents, but shoreline features, tributary inputs and stratification also influence surface currents and must be considered when predicting surface currents.

Figure 4: Mid Lake Surface Currents

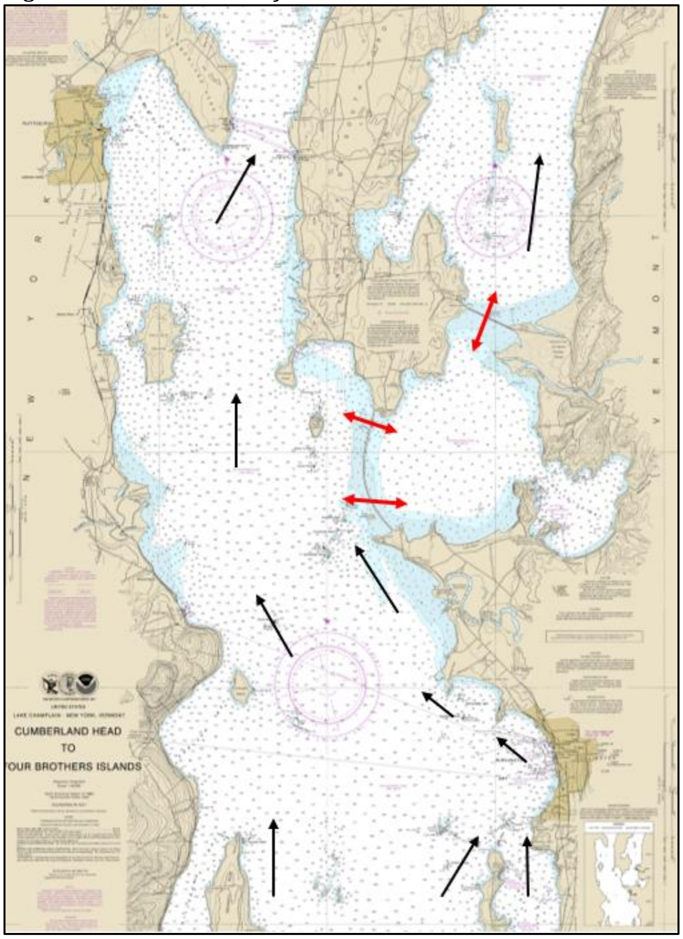


Figure 4 displays surface currents in the middle section of Lake Champlain. The arrows do not reflect the velocity of the surface currents, only normal flow patterns.

The red, double-ended arrows represent narrow openings where the currents are known to shift direction based on wind and water levels.

The black arrows display average surface current movement in the given area.

Wind is the largest factor affecting surface currents, but shoreline features, tributary inputs and stratification also influence surface currents and must be considered when predicting surface currents.

The currents in Lake Champlain have not been extensively studied and there is currently no comprehensive data set or model capable of accurately representing surface currents on the lake.[14] The Vermont EPSCoR Basin Resilience to Extreme Events (BREE) program is currently implementing a 3D coupled physical and biogeochemical model of Lake Champlain that will be capable of modeling localized currents using current weather and buoy data (C. Marti, personal communication, January 28, 2020). Middlebury College is also working on a similar model that may be capable of integrating weather data to create surface current models (T. Manley, personal communication, October 25, 2019). These models may become valuable tools for responders to predict oil and hazardous material transport on the surface and subsurface of the lake.

3.8 Lake level:

The lake level varies naturally throughout the year depending primarily on precipitation and snowmelt. Flooding is expected in the winter and early spring but on rare occasions has also happened in the summer and fall.[9] Many ecosystems along the shores of Lake Champlain and its major tributaries are adapted to natural variations in lake level and are resilient to normal flooding events. In the context of oil or hazardous material spills, the current lake level has a direct effect on which shoreline ecosystems will be affected by a pollutant. The lake has a normal level of 95.5 (29.1 m) feet above mean sea level and it is considered in flood stage at 100 feet (30.5 m).

The United States Geological Service (USGS) Operates multiple gauges on Lake Champlain that monitor Lake level along with other parameters. They can be accessed to see real time lake levels.

- Station # 04294500 Burlington, VT: https://waterdata.usgs.gov/usa/nwis/uv?04294500
- Station # 04294413 Port Henry, NY: https://waterdata.usgs.gov/ny/nwis/uv?site_no=04294413
- Station # 04295000 Rouses Point, NY: https://waterdata.usgs.gov/ny/nwis/uv?site_no=04295000
- Station # 04279085 North of Whitehall, NY: https://waterdata.usgs.gov/nwis/uv?site_no=04279085

The Spring of 2011 produced record level floods on Lake Champlain and its outlet on the Richelieu River. Warm spring temperatures quickly melted a heavy snowpack and record precipitation collectively raised the lake to its highest levels in at least 100 years.[9] The lake rose to a record level of 103.57 feet and remained above flood level for two months. Over 4,000 homes and thousands of acres of farmland were impacted along the lake and Richelieu River basin. [9]

3.9 Wetlands:

One habitat of primary concern within the Lake Champlain watershed is wetlands. There are over 300,000 acres of documented wetlands within the Lake Champlain Basin.[3] They can be viewed on the Lake Champlain Basin Atlas: https://atlas.lcbp.org/nature-environment/wetlands/. Wetlands are extremely important and provide many services to the lake. They help to stabilize shorelines, support numerous natural communities, provide critical habitat, and improve water quality. Many of the wetlands in the basin are directly connected to the shoreline of Lake Champlain and may become inundated with flood water during higher than normal lake levels. If an oil or hazardous material spill were to occur during periods of flooding it could greatly increase environmental damage to the wetlands and decrease the resiliency of the ecosystem altogether.

Figure 5: Spring 2011 North Lake Wetland Flooding[9]

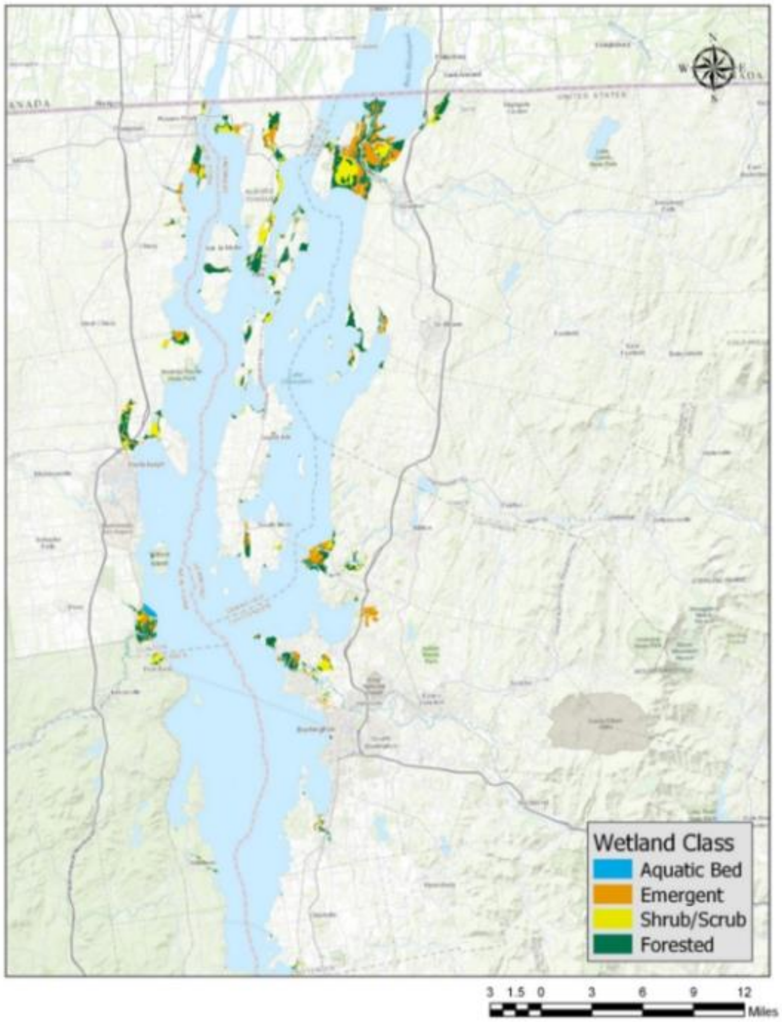


Figure 6: Spring 2011 South Lake Wetland Flooding[9]

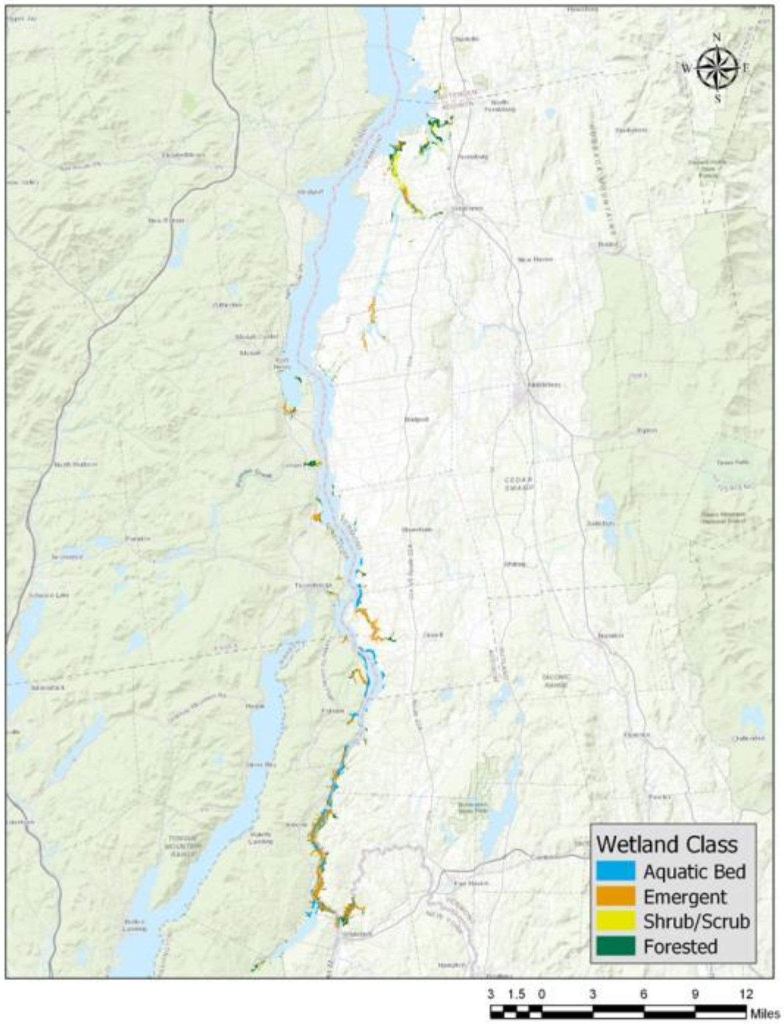


Figure 5 and 6 display wetlands that were impacted by the record spring of 2011 floods on Lake Champlain.[9] Although it is an extreme example, it displays the sensitive environments at risk of being impacted by pollutants associated with flooding events in the basin.

4.0 CLIMATE

The Lake Champlain Basin experiences a sub-humid continental climate, with severe winters. [9] The lake itself is considered a northern temperate lake. In this region, there are four distinct seasons with relatively short summers and long, cold and snowy winters. The higher elevations in the Adirondack and Green Mountains surrounding the lake experience colder temperatures and an average annual precipitation as high as 60 inches (152 cm).[9] The Champlain Valley has warmer average temperatures and an average annual precipitation of as low as 28 inches (71 cm) in part because it resides in the rain shadow of the Adirondack Mountains.[9] The weather in the basin is variable and it is not uncommon to see snowfall from October until May.[15] It is also common to experience at least one major thaw during the winter where temperatures can reach the 60° F (15° C). The Champlain Valley is very susceptible to flooding due to its large basin drainage area and higher levels of mountain snowpack that persist through the rainy spring season.[9]

The Champlain Valley has experienced some extreme weather events including major snowfall, ice storms and tropical storms. In 2011, Tropical Storm Irene tracked up the east coast of the U.S. and dumped 8 inches (20 cm) of rain over portions of Vermont and New York. The precipitation levels exceeded 500-year recurrence levels during this 12-hour storm.[15] The storm caused unprecedented levels of infrastructure damage including structures, roads and bridges. Lake Champlain received a large amount of floodwater including sediment, debris, nutrients and other harmful pollutants.
The long-term climate is what has shaped the hydrology of Lake Champlain, but weather shapes the day-to-day conditions. Temperature, wind, and precipitation have profound effects on oil and hazardous material spills. Weather conditions can increase the weatherization, dissolution and emulsification of pollutants and drive their transport throughout the water column.[16] It is paramount to understand the weather patterns as well as current conditions as they can change quickly and influence the fate of pollutants and disrupt mitigation efforts.[16]

4.1 Weather Data:

The following temperature and precipitation data are for South Hero, Vermont, a community on Grand Isle in the middle of Lake Champlain (Table 6). These seasonal averages are a good representation of the climate on the lake. The average weather data are from the 1981-2010 climate normals published by National Climatic Data Center.

Table 6**:** Seasonal Average Temperature and Precipitation.[17]

Period	Precipitation (In)	Avg Low Temp (°F)	Avg High Temp (°F)
Annual	33.64	37.2	55.1
Spring	7.42	34.0	53.5
Summer	11.19	58.8	78.5
Fall	9.75	41.6	57.6
Winter	5.28	14.2	30.3

A full host of historical weather information for the region including temperatures, snowfall, precipitation, and extreme events can be found at the National Weather Service Burlington, VT website: https://w2.weather.gov/climate/local_data.php?wfo=btv.

4.2 Wind data:

Lake Champlain is largely a north-south lake. Many physical processes are directly driven by winds on the lake. Dominant winds drive surface currents, sediment transport, shoreline erosion and subsurface processes like the internal seiche.[7] Seasonally, the lake generally experiences south/southeast winds in the summer months and north/northwest winds in the winter.

There are recreation-based websites that offer detailed wind reports and predictions from sites directly on the lake. The Windfinder website: www.windfinder.com and the Windy App: https://windy.app both provide detailed on-the-water forecasts and current conditions. Table 7 shows data from the Windfinder website that represents average wind speed and direction averaged from up to 7 different weather sites from March of 2007 until January of 2020.

Table 3: Average wind statistics for Lake Champlain taken between 2007 - 2020.[18]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dominant Wind Direction	W	NNW	N	ENE	ESE	ESE	SE	SE	SE	WNW	WSW	NW
Average Wind Speed (MPH)	9	9	10	10	9	9	8	8	9	9	9	8
Average Wind Gusts	23	23	24	24	23	22	22	23	23	23	23	23

4.3 Remote Weather Stations:

There are remote weather stations available to provide real-time data on Lake Champlain. The Forest Ecosystem Monitoring Cooperative (FEMC) operates three primary atmospheric monitoring stations on Lake Champlain. These are excellent options for real-time weather data.

Burton Island- Southwest of St. Albans Bay
https://www.wrh.noaa.gov/mesowest/timeseries.php?sid=UVM01&num=72

Colchester Reef- West of Colchester Point
https://www.wrh.noaa.gov/mesowest/timeseries.php?sid=UVM02&num=72

Diamond Island - West of Kingsland Bay
https://www.wrh.noaa.gov/mesowest/timeseries.php?sid=UVM03&num=72

4.4 Data Buoys:

SUNY Plattsburgh maintains two data buoys in Lake Champlain, one southeast of Valcour Island and one south of Westport, NY in the Main Lake. The data buoys report surface weather and water temperatures in real time. The data can be accessed at: https://leibensperger.github.io/buoy.html. Another data buoy is operated by Vermont EPSCoR and its data can be accessed at the National Data Buoy Center: https://www.ndbc.noaa.gov/station_history.php?station=45166.
**It should be noted that these buoys are removed for the winter to prevent damage from ice cover.

4.5 Ice cover:

During the winter months the Lake Champlain Basin experiences cold Arctic air and significant snowfall. It is common that the shallow and protected bays around the lake ice over during the coldest times of the year. Partial ice coverage can occur as early as November and last until as late as April.[7] Shallow bays and protected areas like Missisquoi Bay, Mallets Bay and Carry Bay will freeze before the Main Lake. Some years the lake freezes over completely, although it occurs less frequently than it had in the past. Historically the lake freezes completely over between January and March. In the last ten years (2009-2019) the lake has completely frozen over three times.[15] The National Weather Service in Burlington, Vermont, utilizes observations and satellite data imagery to provide current ice coverage maps and reports on their website: https://www.weather.gov/btv/recreation. Ice coverage can complicate traditional response tactics and make access to the lake more difficult. Ice can prevent oil from reaching open water or it can trap oil and hazardous materials below the ice where it is difficult to detect and recover.

5.0 RISK ASSESSMENT

Lake Champlain is an important freshwater resource for drinking water, an abundance of natural habitats, and diverse commercial and recreational opportunities. The lake is imperiled by non-point source pollution and aquatic invasive species but point source pollution threats still exist in the basin. The natural resources of the Lake Champlain Basin are at risk from spills of oil and hazardous materials from railroads, vessel traffic, road systems and commercial/industrial infrastructure along the shorelines.

5.1 Railroad:

Railroads in the Champlain Valley pose the largest risk of a major oil or hazardous material spill into the lake. The New England Central Railway (NECR) transports numerous commodities including chemicals and petroleum products.[19] The Vermont Railway (VTR) carries numerous chemical and petroleum products in addition to other freight and aggregate commodities.[20] The Canadian Pacific Railway (CPR) operates the tracks on the western shore of the lake and poses the largest threat to the basin.[21] Along with an array of other chemical and industrial commodities, CPR has transported Bakken crude oil, a light unrefined product from the upper Midwest. The CPR tracks run from Montreal, Quebec, Canada, along almost 100 miles of Lake Champlain shoreline, often within feet of the lake. At its peak in 2014, CPR was transporting as much as 60 million gallons of Bakken crude oil a week along the shores of Lake Champlain. During this same time, crude by rail transport was at a peak across the country and accidents increased 16-fold between 2010 and 2014.[22] Although crude oil transport has declined rapidly since then, the threat still exists as minor changes in the global oil market could quickly increase transports in the Champlain Valley. Trains in the Champlain Valley regularly carry propane, ethanol, gasoline, ammonia, chlorine and various acids (T. Cosgrove, personal communication, November 12, 2019). Extreme weather events, aging infrastructure and human error can all cause accidents and lead to spills of oil or other hazardous materials into the lake or one of its tributaries.

5.2 Vessel Traffic:

Recreational and commercial vessels pose a risk of oil and hazardous material spills on Lake Champlain. Vessel groundings, collisions, allisions and sinking have occurred on the lake do to its many natural hazards and challenging weather. The lake is a popular connection between the Saint

Lawrence River and the Hudson River, attracting a multitude of transient recreational vessel traffic including large yachts throughout the boating season. Residents own more than 7,000 registered motor boats in the counties adjacent to Lake Champlain (K. Stepenuck, personal communication, February 21, 2020). There is a commercial ferry system on the lake with four separate crossings and a total of 10 ferries, 9 of which are powered by large diesel engines, and one which is driven by cables and shore power. There are 21 commercial passenger vessels that use the lake for tours, dinner cruises and other purposes (E. Green, personal communication, February 21, 2019). Other than construction tenders, and the commercial vessels, there are no large capacity vessels on the lake.

5.3 Road Transportation:

The Champlain Valley is home to a significant network of roads and highway systems that are adjacent to the lake or cross one of the hundreds of tributaries. There are eight bridges that cross directly over the lake near Rouses Point, NY, Swanton, VT, Colchester, VT. The largest span bridge is at the Crown Point Bridge, spanning over 2,000 feet (610m).[3] Road traffic poses a threat to the waters of Lake Champlain given the amount of mixed freight and refined fuel cargos that are transported through the region every day. Spills do occur along highways and road systems and threaten to enter the lake if not immediately contained.

5.4 Shoreside Facilities:

Shoreside facilities include any commercial or industrial businesses that support the storage, use or transportation of oil or hazardous materials. Lake Champlain is home to more than 50 marinas most of which offer fueling services.[4] There is a spill risk from each of these facilities which store and distribute diesel fuel and gasoline products. In Burlington, VT, the Global Oil Facility no longer performs over the water transfers of petroleum products but does lie within 250 ft of the water near Oakledge Park. The transload facility is the only bulk refined products terminal in the state of Vermont. It stores large quantities of home heating oil, diesel fuel, kerosene and other refined products that arrive in rail cars and leave on trucks.[23] The International Paper Company operates its Ticonderoga mill next to the lake in Ticonderoga, NY. It is considered a major oil storage facility (MOSF) by the State of New York with a capacity to store over 400,000 gallons of petroleum products as well as chemicals commonly used in manufacturing paper.[24] Both facilities store large amounts of petroleum products and are subject to natural disasters, floods and mechanical failure that could discharge significant amounts of oil or hazardous materials into Lake Champlain.

6.0 REFERENCES:

1. Lake Champlain Special Designation Act Of 1990, Pub. L. 101-596, 104 Stat. 3006, (1990).
2. Winslow, M. (2008). Lake Champlain A Natural History. Burlington, VT: Lake Champlain Committee.
3. The Lake Champlain Basin Program. The Lake Champlain Basin Atlas. Grand Isle, VT: 2020. Available from: https://atlas.lcbp.org/.
4. The Lake Champlain Basin Program. The Basin Fact Sheet Series Number 3. Grand Isle, VT; 2006.
5. The Lake Champlain Basin Program. [Internet] Grand Isle, Vermont. The Lake Champlain Basin Program; 2020. Lake Champlain Basin History. Available from: https://www.lcbp.org/about-the-basin/history-timeline/
6. Lake Champlain Basin Program. 2018 State of the Lake and Ecosystem Indicators Report. Grand Isle, VT. June 2018.
7. Meyer G.E., and Gruendling G.K. 1979. Limnology of Lake Champlain. New England River Basins Commission: Burlington, Vermont.
8. Voigt B, Lees J, Erickson J. An assessment of the economic value of clean water in Lake Champlain. Lake Champlain Basin Program. 2015 Sep;81:1-53.
9. International Lake Champlain-Richelieu River Study Board. The Causes and Impacts of Past Floods in the Lake Champlain-Richelieu River Basin. International Joint Commission; 2019.
10. Finch, R.G. The Story of the New York State Canals. New York State, State Engineer and Surveyor; 1998.
11. International Lake Champlain-Richelieu River Study Board. Dams and Reservoirs in The Lake Champlain Richelieu River Basin. International Joint Commission; 2019.
12. Rueda, F.J., Schladow S.G., and Clark J.F. 2008. Mechanisms of Contaminant Transport in a Multi-Basin Lake. Ecological Applications, 18(8) Supplement: A72-A88.
13. Hunkins K, Manley TO, Manley P, Saylor J. Numerical studies of the 4-day oscillation in Lake Champlain. Journal of Geophysical Research: Oceans. 1998 Aug 15;103(C9):18425-36.
14. McCormick, M. J., Manley, T. O., Beletsky, D., Foley III, A. J., & Fahnenstiel, G. L. (2008). Tracking the surface flow in Lake Champlain. *Journal of Great Lakes Research*, *34*(4), 721-730.
15. NWS Forecast Office Burlington, VT [Internet]. Burlington, VT: National Weather Service; 2011. Unique Local Climate Data. Available from: https://w2.weather.gov/climate/local_data.php?wfo=btv
16. Mishra AK, Kumar GS. Weathering of oil spill: modeling and analysis. Aquatic Procedia. 2015 Jan 1;4:435-42.
17. NOAA National Centers for Environmental Information [Internet]. Asheville, NC: National Oceanic and Atmospheric Administration. Data Tools: 1981-2010 Normals; South Hero, VT US. Available From: https://www.ncdc.noaa.gov/cdo-web/datatools/normals.
18. Winfinder [Internet]. 2020. Yearly wind and weather averages for Plattsburgh/Lake Champlain. Available From: https://www.windfinder.com/windstatistics/plattsburgh_lake_champlain
19. New England Central Railroad. Overview [Internet]. Darien, CT: Genesee & Wyoming Inc. Available From: https://www.gwrr.com/railroads/north_america/new_england_central_railroad#m_tab-one-panel.

20. Vermont Rail System [Internet]. Burlington, VT: Vermont Rail System. Available From: http://www.vermontrailway.com/index.html.
21. Canadian Pacific Railway [Internet]. Calgary, AB: Networks and Facilities. Available From: https://www.cpr.ca/en/choose-rail/network-and-facilities.
22. Bourguet, L. et al. (2018) Danger on the Tracks: Oil-by-Rail's Threat to Lake Champlain and the Adirondack Region. National Wildlife Foundation. Retrieved from https://www.nwf.org/-/media/Documents/PDFs/NWF-Reports/2018/Danger-on-the-Tracks_2018.ashx
23. Global Companies LLC [Internet]. Waltham, MA: Global Partners Terminals. Available From: https://www.globalp.com/terminals/global-partners-terminals/.
24. New York State Department of Environmental Conservation [Internet]. Albany, NY: Bulk Storage Database Search. Available From: https://www.dec.ny.gov/cfmx/extapps/derexternal/abs/details.cfm.

2.4 Discussion

The *Physical Description of the Lake* section introduces readers to the physical features, hydrology, climate and spill risks of the Lake Champlain region. This information is important to understand the processes that will affect the fate and transport of oil or hazardous materials within the basin. It strengthens the existing contingency plan which is designed to be "a useful tool for responders, providing practical and accessible information about who and what they need to know for an effective response" (U.S. EPA, 2018, p. 4). This new section of the plan will benefit contingency planners, response personnel and resource managers as they plan for and respond to spills of oil and hazardous materials on the lake. Recommendations for future steps that can be taken to further improve response capacity and capability are included in Chapter 5.

CHAPTER 3: OIL SPILL WORKSHOP

3.1. Introduction

Recreational boating is a popular use of coastal areas, inland lakes and rivers. Boaters rely on marinas to provide slips, storage, fueling services, maintenance and pump-outs. There are over 50 marinas on Lake Champlain that deliver valuable services to support the vibrant boating and fishing communities on the lake (Lake Champlain Basin Program, 2006). Marinas pose an inherent threat to water quality from both point and non-point sources from boat maintenance practices to the supply of gasoline, diesel and other petroleum products. Marinas that have greater than 1,320 gallons of above ground or 42,000 gallons of underground storage of petroleum products are required to have Spill Prevention Control and Countermeasure (SPCC) plans in place, but this does not cover all facilities on the lake (U.S. EPA New England, 2005). All marinas should be prepared and trained to prevent and respond to fuel spills. The EPA New England Marina Environmental Management Plan recommends, “The marina owner, general manager, dockmaster and other key managers should receive outside professional environmental training if possible.” (U.S. EPA New England, 2005, p. 38). Regular training reinforces important prevention measures, spill response procedures and emerging technologies or practices that help to reduce pollution incidents from marinas. In 2016, a survey was conducted by Lake Champlain Sea Grant to address the education needs for marinas to support clean boating practices. In the results of the survey, 78% of marinas reported having fuel/oil containment boom on site and 56% were interested in training for their staff to learn how to deploy oil spill equipment (Stepenuck, 2017). To assist marina owners with keeping the waters of

Lake Champlain clean, an oil spill workshop was developed to increase knowledge and awareness.

3.2 Methods

Initially, to develop the most effective training, the 2016 survey of Lake Champlain marina owners was reviewed to better understand the needs of the community. Then training topics were identified that would be valuable to marina owners and employees based on agendas from oil spill training courses held previously in other areas of the United States. Lake Champlain Sea Grant staff, US Coast Guard personnel, VT Department of Environmental Conservation (VTDEC) staff and the President of the Vermont Boat and Marine Association were consulted to prioritize content. The final training curriculum was designed to meet key priorities to maximize usefulness of, and participation in, the training included keeping the training to a half a day, ensuring it was free of charge, and providing an equipment demonstration to teach those with limited experience using spill equipment and materials. To ensure spill response equipment was available during the training, the National Response Corporation (NRC), a local response contractor, was contacted and asked to provide a demonstration including how to deploy containment and absorbent boom in the water. Invitations were sent via email to every marina on Lake Champlain, to fire departments in lakeshore communities, and to Vermont and New York Departments of Environment Conservation spill divisions, county and state emergency managers and state and local hazmat teams. In addition, several regulators from federal and state agencies were invited to teach portions of the course to provide participants with an overview of spill regulations across agencies and jurisdictions. The Vermont Boat & Marine

Association assisted with recruiting marinas to participate. After the course, participants completed an evaluation to collect information about the effectiveness of the workshop and to understand outcomes. This information was passed to Lake Champlain Sea Grant to inform future training needs within the marina and first responder community.

3.3 Results

The workshop was conducted on Wednesday May 1, 2019 at the Lake Champlain Sailing Center on the Burlington waterfront (Figure 2). There were 22 participants representing 6 marinas, fire departments, state hazmat teams, state and federal environmental agencies, and spill contractors.

Figure 2: Oil spill workshop field demonstration. NRC Employees demonstrate the proper deployment of containment boom and portable skimmer. Photo Credit: Kristine Stepenuck.

Table 2 shows the agenda for the half day of training, demonstration and discussions. It can be used for future training opportunities.

Table 2: Oil Spill Workshop Agenda, May 1, 2019.

Subject	**Presenter**	**Schedule**	**Total Time**
Arrival/Sign-in		0815-0830	15 Min
Intro/Welcome	Jason Scott	0830 - 0850	20 Min
Spill Notifications	VTDEC; USCG; EPA	0850 - 0905	15 Min
Environmental Health and Safety (OSHA Regs)/PPE	Jason Scott; VTDEC	0905 - 0925	20 Min
Break		0925 - 0935	10 Min
Hazardous Waste Management (From Spills)	VTDEC; EPA	0935 - 0955	20 Min
Hands on Training w/ Boom, Sorbents, skimmer,	NRC; USCG; VTDEC	0955 - 1125	90 Min
Resources/Handouts/ Final Thoughts/Questions	Jason Scott /Mike O'Brien	1125- 1150	25 Min

The contributors and presenters during the workshop are listed below:

- Facilitator – Jason Scott
- VTDEC –James Donaldson
- USCG Sector Northern New England – PO Barry Spiro; PO John Fanelli
- USCG Station Burlington – Ed Green
- VT Boat & Marine Assoc. – Mike O'Brien
- NRC Environmental Services – John Kelliher
- VT Hazardous Material Response Team – Bruce Martin
- U.S. EPA Region 2 – Carl Pellegrino

The National Response Corporation displayed and deployed their response equipment at the Coast Guard launch ramp on the Burlington waterfront. Representatives from the VTDEC, U.S. Coast Guard, and U.S. EPA presented applicable regulations and notification procedures in the event of a spill. The information presented during the workshop will be available on the Lake Champlain Sea Grant website on a page dedicated to further educate the public, marine industry and responders on oil and hazardous material spill preparation and response.

3.4 Discussion

The oil spill workshop attracted a diverse group of regulators and marina owners. It provided an opportunity to share knowledge, allow participants to better understand local regulations and to observe oil spill containment tactics. In the post workshop survey, 100% of participants said the workshop met their expectations and 80% said they expected to use knowledge, skills, or practices learned at the workshop in the next 6-12 months. The participants indicated they would implement safety and spill response plans, post required notification phone numbers, purchase additional spill response equipment and locate or purchase spill containment boom.

There are a few ways in which future workshop or training sessions could be improved and strengthened. First, travel to Burlington, VT, proved difficult for the New York marinas and first responder agencies. As such, it would be more effective to offer events in both Vermont and New York in the future. Second, participation by fire departments was limited. Having more fire departments involved would be a good way to connect marina staff with the first responders who will come to assist in the case of a discharge of gasoline or diesel fuel into the lake. Fire departments are often the first on scene and could provide important support for marina staff to help mitigate the effects of a spill on their facility. Third, marina staff would benefit from Hazardous Waste Operations and Emergency Response (HAZWOPER) training opportunities. HAZWOPER certification was not included in this workshop because the initial training requires eight hours of classroom time and a certified trainer, and the cost would be much higher. Providing HAZWOPER training to marina owners and staff is designed to "identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations" (29CFR 1910.120(b)(1)(i)). HAZWOPER covers Occupational Safety and Health Administration (OSHA) standards for oil and hazardous material handling and spill response. This training is required for marina staff to assist in a spill on Lake Champlain from another facility or responsible party but not if it originates from their own facility (29 CFR 1910.120(a)(3)). Finally, if there was a way to incentivize marinas or other industry members to participate in the training, participation could be increased. The time of year, length of training and location are all factors that influence participation. Marinas typically have temporary staff with short working seasons so if the states or other organizations could provide a financial incentive or recognition of participants' commitment to reducing spills, it may increase the priority to have marina staff attend this type of workshop. As an alternative, publications, presentations, and online training links will be posted on the Lake Champlain Sea Grant website to encourage marinas and other industry representatives to educate their staff and find ways to reduce spills.

CHAPTER 4: SCIENTIFIC SUPPORT NETWORK

4.1 Introduction

The need to incorporate scientific knowledge and resources into spill response operations is critical to understanding and reducing environmental damage. The National Oceanic and Atmospheric Administration (NOAA) has an Emergency Response Division (ERD) staffed with Scientific Support Coordinators (SSC's) who directly support Federal On-Scene Coordinators from the US Coast Guard and the Environmental Protection Agency (NOAA, 2015). The NOAA SSC's are tasked with providing support in making operational decisions, coordinating on-scene scientific activity and integrating scientific expertise during spill response. The SSC's are regionally based, with only 11 people in this position across the whole country, including Alaska and Hawaii. Thus, each has broad geographic area of responsibility, which can impact response times and familiarity with the area. For the Lake Champlain region, the responsible SSC is in Boston, MA and is responsible for 6 states, including both Long Island and upstate New York. To assist the SSC as well as the Vermont and New York Department of Environmental Conservation spill divisions, a Scientific Support Network database was created for the Lake Champlain Basin. This database directly supports the Clean Water Act's Area Contingency Plan requirement to "compile a list of local scientists, both inside and outside Federal Government service, with expertise in the environmental effects of spills of the types of oil typically transported in the area, who may be contacted to provide information or, where appropriate, participate in meetings of the scientific support team convened in response to a spill" (CWA 311(j)(4)(C)(v)). The database provides a list of academic professionals with unique knowledge or research experience on Lake Champlain. Their relevant expertise can be accessed by spill planners and responders to help influence area specific protocols. There is a list of research vessels and water quality analysis tools that could be used during a spill on the lake to gauge contamination levels and environmental damage. It also provides a list of academic organizations that assist in research, education and public outreach in the Champlain Valley.

4.2 Methods

The scientific support network was modeled after the University of Rhode Island Scientific Support for Emergency Environmental Incidents (SSEER) program (The University of Rhode Island, 2020). To build the database, a survey was conducted to understand the needs of the regulatory community representing Lake Champlain. A review and approval were requested through the University of Vermont (UVM) Institutional Review Board (IRB). The review was needed because the survey involved human subjects and contributed to generalizable knowledge.

The survey was designed to gather information about important scientific expertise, information and equipment that would be valuable to the Incident Management Team during a response to an oil spill, hazardous material incident or natural disaster affecting Lake Champlain. The 10-question survey asked respondents to consider scientific needs related to collection and containment strategies, environmental protection, wildlife management, and human health aspects of an environmental incident if one were to occur on Lake Champlain (Appendix A). All of the questions were qualitative and required participants to type answers in their own words. The survey ran for a 30-day period through an online survey management program called Qualtrics. The survey was sent to:

- EPA Region 1 On-Scene Coordinators
- EPA Region 2 On Scene Coordinators
- US Coast Guard Station Burlington Marine Safety Specialist
- U.S. Coast Guard Sector Northern New England Incident Management Division staff
- U.S. Coast Guard District One Response Division staff
- NOAA Scientific Support Coordinator
- Vermont Department of Environmental Conservation Spill Division staff
- Vermont State Hazardous Material Response Team
- New York State Department of Environmental Conservation Statewide Office staff
- New York State Department of Environmental Conservation Region 5 staff
- Essex County, NY County Office of Emergency Services staff
- Clinton County, NY Office of Emergency Services staff
- Canadian Pacific Railway Hazardous Materials Officer

These entities represent the federal, state and local agencies with jurisdictional responsibility to plan for and respond to oil and hazardous material spills in Lake

Champlain. The survey was sent to 30 different agency representatives and 15 responded for an overall 50% completion rate representing all of the major agencies.

Survey results were compiled to inform follow-up research and interviews to identify contacts to include in the database. The results were first organized by area of concern (e.g., wildlife management, environmental protection) and then individual responses were grouped based on similarities and key words. Next, the consolidated scientific support requests were categorized as:

- Already in the existing contingency plan
- Needs to be added to the existing contingency plan
- Resource to find for inclusion in the scientific support network database
- Incident-specific information / not applicable

The resources identified as “already in the existing contingency plan” or “incident-specific information” were not addressed in this project. The “needs to be added to the existing contingency plan” resources were examined further and used to make recommendations for the existing Lake Champlain Area Contingency Plan in Chapter 5. The “resource to find for inclusion in the scientific support network database” category was used as the basis for the development of the resource database (Tables 3-9).

Academic websites, research papers and personal conversations were used to find the scientific resources that were requested by the spill response community. Scientific resources identified included people, equipment, facilities and organizations. University professionals were interviewed to identify resources with specific capabilities or expertise as identified in the survey. University and organizational websites were examined to identify relevant laboratory equipment, field analysis tools, and research boats.

4.3 Results

The various tables that identify critical support resources in the Scientific Support Network database will be hosted on a webpage maintained by Lake Champlain Sea Grant or another group closely tied to the management of Lake Champlain scientific information and research. The database is shown in (Tables 3-9).

Identified resources were included in the database if they were currently available and associated with the academic community in the Lake Champlain basin (Tables 3-5). Primary research topics, area of expertise and contact information were included for each person listed in the database. Equipment, facilities and boats were listed with their capabilities and physical location (Tables 6-7). Organizations were listed with their primary mission and website to allow users to access additional information (Table 8). Finally, an easy to search resource matrix was created to allow users to quickly access professionals with expertise in specific areas (Table 9).

Table 3: Scientific Support Network – University of Vermont.

First Name	Last Name	Title	E-mail	Phone	Institution or Organization	Area of Expertise
William (Breck)	Bowden	Chair of Watershed Science & Planning, Director of Water Resources and Lake Studies Center, Lake Champlain Sea Grant	breck.bowden@uvm.edu	802-656-2912	University of Vermont	Watershed science & management, stream ecology
Steve	Cluett	Research Vessel Captain	steve.cluett@gmail.com	802-858-2153	University of Vermont	Research vessel captain, aquatic research equipment specialist
Ellen	Marsden	Professor	ellen.marsden@uvm.edu	802-656-0684	University of Vermont	Ichthyology, fisheries ecology, fish behavior, aquatic invasive species
Clelia	Marti	Assistant Professor	Clelia.Marti-De-Ocampo@uvm.edu	802-656-8793	University of Vermont	Physical and biogeochemical processes in surface water systems, field monitoring, numerical modeling of surface water systems, environmental fluid dynamics
Mindy	Morales-Williams	Assistant Professor	ana.morales@uvm.edu	802-656-3009	University of Vermont	Biogeochemical nutrient cycling, algal and microbial ecology, harmful phytoplankton blooms in freshwater and coastal systems
Brittany	Mosher	Assistant Professor	brittany.mosher@uvm.edu	802-656-3105	University of Vermont	Disease and population ecology, quantitative ecology, conservation decision-making,

Table 3: Scientific Support Network – University of Vermont.

First Name	Last Name	Title	E-mail	Phone	Institution or Organization	Area of Expertise
						herpetology, conservation biology
James (Jed)	Murdoch	Associate Professor, Director of Wildlife & Fisheries Biology Program	james.murdoch@uvm.edu	802-656-2912	University of Vermont	Wildlife ecology, Mammals. Conservation biology
Jarlath	O'Neil-Dunne	Director, Spatial Analysis Lab	jarlath.oneil-dunne@uvm.edu	802-656-3324	University of Vermont	Geospatial technology, wildlife habitat mapping, land cover change detection, community health, water quality modeling, drone operator
George	Pinder	University Distinguished Professor	gpinder@uvm.edu	802-656-8697	University of Vermont	Hydrology, groundwater contamination, modeling
Donna	Rizzo	Professor, Civil and Environmental Engineering	drizzo@uvm.edu	802-656-1495	University of Vermont	Water resources, hydrology, environmental & public health
Andrew	Schroth	Research Associate Professor	Andrew.Schroth@uvm.edu	802-656-3481	University of Vermont	Low temperature geochemistry, hydrology, environmental mineralogy
Kristine	Stepenuck	Extension Assistant Professor; Lake Champlain Sea Grant Extension	kris.stepenuck@uvm.edu	802-656-8504	University of Vermont	Watershed science, water quality monitoring, citizen science, macroinvertebrates

Table 3: Scientific Support Network – University of Vermont.

First Name	Last Name	Title	E-mail	Phone	Institution or Organization	Area of Expertise
Jason	Stockwell	Professor, Director of Rubenstein Ecosystem Science Laboratory	jason.stockwell@uvm.edu	802-656-3009	University of Vermont	Aquatic ecology, wildlife and fisheries biology, limnology
Alan	Strong	Professor	allan.strong@uvm.edu	802-656-3009	University of Vermont	Avian ecology, conservation biology, landscape ecology

Table 4: Scientific Support Network – State University of New York (SUNY) Plattsburgh.

First Name	Last Name	Title	E-mail	Phone	Institution or Organization	Area of Expertise
Mary	Alldred	Assistant Professor of Environmental Science	malld001@plattsburgh.edu	518-564-4112	SUNY Plattsburgh	Aquatic ecology, wetlands, aquatic invasive species
Eileen	Allen	Coordinator, GIS Laboratory	eileen.allen@plattsburgh.edu	518-564-2020	SUNY Plattsburgh	GIS, remote sensing, wetlands mapping
Danielle	Garneau	Associate Professor of Environmental Science	danielle.garneau@plattsburgh.edu	518-564-4073	SUNY Plattsburgh	Wildlife ecology, herpetology, mammals, microplastics in Lake Champlain, citizen science
Steve	Kramer	Director of Lab Studies at W.H. Miner Institute; Adjunct Lecturer	kramersr@plattsburgh.edu	518-564-2401	SUNY Plattsburgh	Water chemistry, agricultural runoff, Lake Champlain water quality, remote monitoring
Eric	Leibensperger	Associate Professor of Environmental Science	eleib003@plattsburgh.edu	518-564-4104	SUNY Plattsburgh	Environmental chemistry, climate systems, physical limnology, data buoys, air quality, Lake Champlain water quality
Timothy	Mihuc	Director, Lake Champlain Research Institute	timothy.mihuc@plattsburgh.edu	518-564-3039	SUNY Plattsburgh	Lake Champlain Research Institute, aquatic ecology, invertebrate community dynamics, aquatic invasive species
Luke	Myers	LCRI Field Operations Manager	myerslw@plattsburgh.edu	518-564-3044	SUNY Plattsburgh	Research vessel captain, aquatic research equipment specialist, aquatic entomology
Edwin	Romanowicz	Director, Center for Earth & Environmental Science	edwin.romanowicz@plattsburgh.edu	518-564-2152	SUNY Plattsburgh	Hydrogeochemistry, geology, water sampling, hydrological modeling

Table 5: Scientific Support Network – Middlebury College, Saint Michael's College, Castleton State University.

First Name	Last Name	Title	E-mail	Phone	Institution or Organization	Area of Expertise
Erin	Eggleston	Assistant Professor of Biology	eeggleston@middlebury.edu	802-443-5779	Middlebury College	Microbial ecology, field biology, sediments
Richard	Furbush	Research Vessel Captain	N/A	802-363-2100	Middlebury College	Research vessel captain, aquatic research equipment specialist
Tom	Manley	Assistant Professor of Geology	tmanley@middlebury.edu	802-443-3114	Middlebury College	Hydrodynamics of Lake Champlain, physical oceanography, coastal processes
Patricia	Manley	Assoc. Dean for the Sciences; Professor of Geology	manley@middlebury.edu	802-443-5430	Middlebury College	Lake Champlain hydrodynamics, marine geology, sedimentology,
Eric	Moody	Assistant Professor of Biology	ekmoody@middlebury.edu	802-443-2556	Middlebury College	Ecosystem ecology, harmful algal blooms, zooplankton communities
Pete	Ryan	Professor of Geology	pryan@middlebury.edu	802-443-2557	Middlebury College	Geology, hydrology, groundwater chemistry
Doug	Facey	Professor of Biology	dfacey@smcvt.edu	802-654-2625	Saint Michael's College	Ichthyology, Lake Champlain fish, fish physiology and ecology
Declan	McCabe	Professor of Biology	dmccabe@smcvt.edu	802-654-2626	Saint Michael's College	Aquatic ecology, macroinvertebrates, wetlands
Andrew	Vermilyea	Chair, Environmental Science Program	andrew.vermilyea@castleton.edu	802-468-1289	Castleton State University	Biogeochemistry; nutrient transport

Table 6: Scientific Support Network – Equipment and Facilities.

Resource	Institution	Capabilities	Website	Location
Lake Champlain Research Institute (LCRI) Analytical Laboratory	SUNY Plattsburgh	Dionex ICS-2000 RFIC Ion Chromatograph; Bran-Luebbe Auto Analyzer, (two channels; total N&P); Perkin Elmer AAnalyst 400 Atomic Absorption Spectrophotometer; Perkin Elmer Optima 7000DV Inductively Coupled Plasma Optical Emission Spectrometer; Thermo Flash 2000 Elemental Analyzer, NC sediments analyzer;Thermo HiPerTOC, total organic carbon analyzer.	https://www.plattsburgh.edu/academics/lake-champlain-research-institute/facilities-equipment.html	The Hudson Annex SUNY Plattsburgh 115 Broad Street Plattsburgh, NY 12901
Lake Champlain Research Institute (LCRI) Field Equipment	SUNY Plattsburgh	Stream velocity meters, backpack electroshocker; Eureka Water Quality Multiprobe for pH, DO, conductivity and turbidity; Free fall core sampler capable of operating at 120m depth (Eckmann Dredge); Various limnological sampling gear including plankton nets, water samplers, a tucker trawl and a bottom fish trawl.	https://www.plattsburgh.edu/academics/lake-champlain-research-institute/facilities-equipment.html	The Hudson Annex SUNY Plattsburgh 115 Broad Street Plattsburgh, NY 12901

Table 7: Scientific Support Network – Equipment and Facilities.

Resource	Institution	Capabilities	Website	Location
Analytic laboratory and field equipment available at Middlebury College	Middlebury	ICAP mass spectrometer, scanning electron microscope, X-Ray diffractometer, sediment analysis facility, field surveying equipment,	http://www.middlebury.edu/academics/geol/facilities	McCardell Bicentennial Hall 276 Bicentennial Way Middlebury, VT 05753
Rubenstein Ecosystem Science Laboratory	UVM	1300-sqft adaptable wet laboratory, state-of-the-art teaching laboratory, compound and dissecting microscopes, microscope room with multiple compound and dissecting microscopes and associated image analysis systems; acid wash room; walk-in freezer and refrigerator space; -80˚C freezer; gas chromatograph ; TOC analyzer equipped with a TN analyzer, Lachat QuikChem FIA+ 8000 auto-analyzer; Shimadzu UV-1601 single beam spectrophotometer, 4-chamber respirometer; SCUBA gear, Drying ovens, ROV, Benthic Camera, Seabird CTD,	https://www.uvm.edu/rsenr/rubensteinlab/laboratory-facilities	Rubenstein Ecosystem Science Lab 3 College Street Burlington, VT 05401

Table 8: Scientific Support Network Research Boats.

Boat	Length	Power	Type	Capabilities	Website	Location
"Gruendling"	32 ft.	333 hp	Aluminum	A- frame and winch for equipment deployment; computers; navigational equipment	https://www.plattsburgh.edu/academics/lake-champlain-research-institute/facilities-equipment.html	Valcour Educational Center 3712 State Rte 9 Peru, NY 12972
Lund	21 ft.	115 hp	V- Hull	Trailerable boat, includes equipment winch	https://www.plattsburgh.edu/academics/lake-champlain-research-institute/facilities-equipment.html	Valcour Educational Center 3712 State Rte 9 Peru, NY 12972
"Linnaeus"	24 ft.	150 hp	Aluminum Semi - V Hull	Trailerable boat, 10 person max	https://www.plattsburgh.edu/academics/lake-champlain-research-institute/facilities-equipment.html	Valcour Educational Center 3712 State Rte 9 Peru, NY 12972
R/V David Folger	48 ft.	Twin 250 hp	Aluminum Catamaran	Onboard equipment includes: acoustic doppler current profilers, a multi-beam echo sounder, a CTD rosette and sediment corers.	http://www.middlebury.edu/academics/geol/facilities/newvessel	Basin Harbor Club Marina 4800 Basin Harbor Rd, Vergennes, VT 05491
R/V Melosira	45 ft.	275 hp	Downeast Cruiser	A-Frame and winch for equipment deployment, onboard computers, water sampling, plankton sampling, sediment coring, deploying and maintaining in-situ sensors, gill netting, bottom and mid-water fish trawling, hydroacoustic sampling	https://www.uvm.edu/rsenr/rubensteinlab/research-vessel-melosira-and-other-boats	Rubenstein Ecosystem Science Lab 3 College Street Burlington, VT 05401
C-Hawk	22 ft.	115 hp	Center Console	Trailerable boat, used for sampling and buoy maintenance	https://www.uvm.edu/rsenr/rubensteinlab/research-vessel-melosira-and-other-boats	Rubenstein Ecosystem Science Lab 3 College Street Burlington, VT 05401

Table 9: Scientific Support Network Research Boats.

Boat	Length	Power	Type	Capabilities	Website	Location
Jon Boat	16 ft.	8 hp	Aluminum	Trailerable boat, useful for variety of tasks	https://www.uvm.edu/rsenr/rubensteinlab/research-vessel-melosira-and-other-boats	Rubenstein Ecosystem Science Lab 3 College Street Burlington, VT 05401
Inflatable	15 ft.	20 hp	Inflatable	Trailerable/portable boat, used for water sampling, good for smaller water bodies, easy to launch	https://www.uvm.edu/rsenr/rubensteinlab/research-vessel-melosira-and-other-boats	Rubenstein Ecosystem Science Lab 3 College Street Burlington, VT 05401

Table 11: Scientific Support Network – Organizations.

Resource	UVM	Middlebury	SUNY Platt	Other	Mission and Capabilities	Website	Location
The University of Vermont Spatial Analysis Lab	X				Geographic Information System (GIS) research facility. The scope of their work includes ecosystem assessments, biodiversity analysis, land-cover mapping, and conserved lands planning to scenario modeling, LiDAR processing, web-based mapping, and even transportation analysis. Qualified pilots and drones.	http://www.uvm.edu/rsenr/sal/	The University of Vermont Aiken Center 81 Carrigan Drive Burlington, VT 05405
UVM Extension Program	X				Integrates higher education, research and outreach to help put knowledge to work in families and homes, farms and businesses, towns and the natural environment. Volunteer coordination and stakeholder outreach.	https://www.uvm.edu/extension	The University of Vermont Morrill Hall Burlington, VT 05405
Lake Champlain Sea Grant	X		X		Supports research and education that informs land and water management practices and policy decisions. Conducts regular outreach to basin residents, students and teachers, community and business leaders, agency staff and the research community.	https://www.uvm.edu/seagrant/	The University of Vermont Aiken Center 81 Carrigan Drive Burlington, VT 05405
Lake Champlain Maritime Museum				X	A research and educational institution dedicated to preserving and sharing cultural and natural resources of Lake Champlain. Archaeology, ROV operation, SCUBA diving team and historical preservation.	https://www.lcmm.org/	4472 Basin Harbor Road, Vergennes, VT 05491
Lake Champlain Basin Program				X	Works in partnership with government agencies from New York, Vermont, and Québec, private organizations, local communities, and individuals to coordinate and fund efforts that benefit the Lake Champlain Basin's water quality, fisheries,	https://www.lcbp.org/	54 West Shore Road Grand Isle, VT 05458

Table 11: Scientific Support Network – Organizations.

Resource	UVM	Middlebury	SUNY Platt	Other	Mission and Capabilities	Website	Location
					wetlands, wildlife, recreation, and cultural resources.		
Vermont Established Program to Stimulate Competitive Research (EPSCoR). Basin Resilience to Extreme Events (BREE) in the Lake Champlain Basin	X	X		X	A $20 million grant from the National Science Foundation to study and promote resiliency in the Lake Champlain Basin. Developing an integrated model that will be used to test impacts of management scenarios on Lake Champlain water quality, and can identify strategies for preserving infrastructure, environmental health and drinking water quality. Project ends in 2021.	https://epscor.w3.uvm.edu/2/node/2186	N/A
Lake Champlain Research Consortium	X	X	X	X	Coordinates and facilitates research and scholarship of the Lake Champlain ecosystem and related issues; provides opportunities for training and education of students on lake issues. Aids in the dissemination of information gathered through lake endeavors.	https://www.lcbp.org/about-us/partners/lake-champlain-research-consortium/	The Hudson Annex SUNY Plattsburgh 115 Broad Street Plattsburgh, NY 12901
Lake Champlain Research Institute			X		An advanced research and educational facility at SUNY Plattsburgh focusing on the health of Lake Champlain. The primary objective is to promote student research and the Institute is actively involved in research in the Lake Champlain Basin.	https://www.plattsburgh.edu/academics/lake-champlain-research-institute/index.html	The Hudson Annex SUNY Plattsburgh 115 Broad Street Plattsburgh, NY 12901

Table 11: Scientific Support Network – Organizations.

Resource	UVM	Middlebury	SUNY Platt	Other	Mission and Capabilities	Website	Location
The William H. Miner Agricultural Research Institute			X	X	Conducts research programs that apply basic science to contemporary problems confronting the dairy and equine industries. Includes wetland and wildlife ecology, water quality monitoring, agriculture and the environment. Non-profit education facility including water quality laboratory and on-site housing.	http://www.whminer.com/	1034 Miner Farm Road Chazy, NY 12921
Vermont Cooperative Fish and Wildlife Research Unit	X			X	Created to enhance graduate education in fisheries and wildlife sciences and to facilitate research among natural resource agencies and universities on topics of mutual concern. Areas of emphasis include sea-lamprey control, Atlantic salmon restoration, acoustical sampling, food-webs, energetics, landscape ecology, conservation biology, and population modeling.	https://www1.usgs.gov/coopunits/Vermont/	The University of Vermont Aiken Center 81 Carrigan Drive Burlington, VT 05405

Table 12: Scientific Support Matrix.

Names	**William (Breck) Bowden**	**Steve Cluett**	**Ellen Marsden**	**Clelia Marti**	**Mindi Morales-Williams**	**Brittany Mosher**	**James (Jed) Murdoch**	**Jarlath O'Neil-Dunne**	**George Pinder**	**Donna Rizzo**	**Andrew Schroth**	**Kristine Stepenuck**	**Jason Stockwell**	**Alan Strong**
Institution	University of Vermont													
Area of Expertise														
Aquatic Ecology	X			X								X	X	
Birds														X
Currents/Circulation				X										
Drone Pilot								X						
Ecology/Habitats	X		X			X	X							X
Fisheries Science			X										X	
Geology/Hydrogeology											X			
GIS/ Mapping								X						
Herpetology						X								
Hydrologic Modeling				X					X					
Hydrology									X	X	X			
Limnology				X	X									
Macroinvertebrates												X		
Microbial Ecology					X									
Research Equipment		X											X	
Vessel Captain		X												
Water Chemistry	X										X			
Water Sampling	X				X							X		
Watershed Science	X									X	X	X	X	
Wetlands														
Wildlife							X							

Table 13: Scientific Support Matrix.

Names	**Mary Alldred**	**Eileen Allen**	**Danielle Garneau**	**Steve Kramer**	**Eric Leibensperger**	**Timothy Mihuc**	**Luke Myers**	**Edwin Romanowicz**	**Erin Eggleston**	**Richard Furbush**	**Tom Manley**	**Patricia Manley**	**Eric Moody**	**Pete Ryan**	**Doug Facey**	**Declan McCabe**	**Andrew Vermilyea**
Institution	SUNY Plattsburgh								Middlebury						Saint Michael's College		Castleton State
Area of Expertise																	
Aquatic Ecology	X					X	X		X				X		X	X	
Birds																	
Currents/Circulation											X	X					
Drone Pilot																	
Ecology/Habitats																	
Fisheries Science															X		
Geology/Hydrogeology								X			X	X		X			
GIS/ Mapping		X															
Herpetology			X														
Hydrologic Modeling								X									
Hydrology								X						X			
Limnology				X							X	X					
Macroinvertebrates							X						X			X	
Microbial Ecology									X								
Research Equipment					X	X	X			X							
Vessel Captain							X			X	X						
Water Chemistry				X	X			X						X			X
Water Sampling				X													
Watershed Science						X											
Wetlands	X	X														X	
Wildlife			X														

4.4 Discussion

The database will provide federal, state and local responders with a quick way to connect to important scientific resources to better support response operations during a spill or other environmental disaster. This list will be distributed to the U.S. EPA, U.S. Coast Guard and state spill response personnel for possible inclusion in government contingency plans. In Rhode Island the scientific support network fortunately has not needed to be utilized for an actual incident (The University of Rhode Island, 2020). It has been used during oil and hazardous material spill exercises and planning efforts within the state. The current manager of the program recommended several best practices to increase the value of the network (P. August, personal communication, July 29, 2019).

- Coordinate with the State: Work with the state Department of Environmental Conservation to increase awareness of the scientific support network and discuss how it could be utilized during an incident.
- Development of Rules of Engagement: The development of rules, by-laws or some type of coordinating document will help to frame the organization and establish basic guidelines for supporting an incident response.
- Yearly Update: The database should be reviewed once a year to ensure listed resources are still available and contact information is correct.
- Annual Meeting: At least once during the year, meet with key regulators and those listed in the database. Topics of discussion can include training, case studies, administrative procedures, and capability presentations.

The Scientific Support network provides federal, state and local responders with important scientific resources during an environmental disaster. It also provides the academic community an opportunity to utilize their skills, research and equipment to help protect local natural resources and serve their communities. It is intended that Lake Champlain Sea Grant will maintain this database. The spreadsheets are intended to be listed on the Lake Champlain Sea Grant website with all the information presented in this paper except contact information. Personal contact information will be made available to federal, state and local response agencies but will not be listed on a public website.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

After examining the results of my survey and conducting extensive research into the Lake Champlain Basin, I have identified several areas for improvement with regard to oil spill planning and preparedness. In the scientific support survey listed in Chapter 4, there were requests for information that were already available but needed to be listed in the Lake Champlain Contingency Plan to assist response personnel. There was also information that was requested but does not yet exist in the region, like Environmental Sensitivity Index (ESI) maps and comprehensive surface current maps. The addition of these resources would increase preparedness in the Lake Champlain region and allow first responders to make more informed operational decisions to better protect sensitive natural resources.

5.1 Environmental Sensitivity Index Maps

Environmental Sensitivity Index (ESI) maps have been produced for most marine coastal environments in the United States as well as the Great Lakes and the Hudson River. These maps identify shoreline types by sensitivity to oil spills and identify fish and wildlife resources that may be present in specific areas (Jensen, Halls, & Michel, 1998). They are crucial for developing protection strategies during a spill response especially in the early phases. Lake Champlain does not currently have a published ESI map. In the survey conducted for this project, 73% of the survey participants identified the need for either sensitive habitat maps or maps of where sensitive species are present. Both needs would be met with published ESI maps that could guide response efforts for specific geographic locations. These maps are typically produced through a government contractor. To increase the scientific and academic investment in spill preparedness, the University of Vermont and Lake Champlain Sea Grant may be able to assist in developing ESI maps for Lake Champlain. They have experience with complex datasets and access to a diverse group of professionals who could provide excellent value to the project. Based on the survey, the development of ESI maps would satisfy many of the scientific support requests from the regulatory community.

5.2 Surface Current Research

Oil and hazardous material trajectory models are critical tools in any spill to estimate the fate and effects of a spill. For these complex models to be accurate, they require "exact information on the environmental conditions such as winds, currents, waves, turbulence, salinity, temperature, and solar insolation for the accurate simulation of movement of oil slicks" (Kim, Yang, Oh, & Ouchi, 2014). There has been little research conducted on surface currents in Lake Champlain. Limited drifter studies were completed in the 1970's and documented in the *Limnology of Lake Champlain* (Meyer & Gruendling, 1979). Middlebury College performed more recent studies on surface currents in 2008 but there is still a lack of comprehensive surface current information in the lake (McCormick, Manley, Beletsky, Foley III, & Fahnenstiel, 2008). A model of surface currents for the lake could provide responders an accurate view of where oil and other floating pollutants will move along the surface. Currently there are too many unknown variations and not enough observations on Lake Champlain to produce a comprehensive model of surface currents.

More research could produce data that would be critical to support accurate trajectory modeling for oil and hazardous material spills.

Currently, Dr. Tom Manley (Middlebury College), Dr. Liv Herdman (U.S. Geological Survey) and Dr. Herman Kernkamp (Deltares, Netherlands) are working on a three-dimensional hydrodynamic numerical model of Lake Champlain (T. Manley, personal communication, March 26, 2020). They are using an open source software called the Delft 3D Flexible-Mesh suite (D-flow-FM). The software was created by the company Deltares in the Netherlands. The model is capable of displaying thermal, and circulation variability within the lake based on atmospheric variables, river inputs and the lake level. Physical structures such as bridges, breakwaters, causeways and bottom bathymetry are also built into the model. This model is very capable but not yet complete. It is not an emergency response option in its current state.

The Vermont Established Program to Stimulate Competitive Research (EPSCoR) Basin Resilience to Extreme Events (BREE) program has sponsored a separate project to develop a coupled three-dimensional hydrodynamic-water quality model (C. Marti, personal communication, March 31, 2020). This project is using the three-dimensional Aquatic Ecosystem Model 3D (AEM3D) and is led by Dr. Clelia Marti at the University of Vermont. The hydrodynamics component in this model predicts velocity, temperature, salinity and tracer distributions in standing waters that are subjected to external forcing from the atmosphere, river surface in and out flows, groundwater flows and built structures. The water quality component in AEM3D is dynamically coupled to the hydrodynamics component to simulate the fate and transport of physical, chemical and biological state variables. It houses a series of mathematical equations representing biogeochemical processes that influence water quality including primary and secondary production, nutrient and metal cycling, oxygen dynamics and movement of the sediment. This model is still under development and will be complete prior to 2021 when the BREE program expires.

5.3 Contingency Plan Additions

The Lake Champlain Contingency Plan includes many valuable contacts from federal, state, local and international agencies and organizations. It is missing some key contacts and information that may be important during the early phases of an environmental response on the lake. These additions were identified through the survey that was distributed to response agencies as described in Chapter 4. The lead planners for the Lake Champlain Contingency Plan should consider adding the following agencies and organizations:

- Abenaki Tribal Liaison: There are four Abenaki Tribes that are recognized by the state of Vermont who traditionally inhabited the Champlain Valley. The Abenaki have significant cultural ties to the lake. They are organized and should be notified of incidents affecting the lake especially the Abenaki Nation at Missisquoi Bay: https://www.abenakination.com/.
- Lake Champlain Ferries: The ferry system would potentially be the largest commercial operation disrupted by a spill on the lake. The Ferries could also provide valuable logistical support during an incident including

personnel and equipment transport, temporary storage platforms and on water observations. https://ferries.com/

- State Park and Beach Managers: Public land managers can be important resources for local information, evacuation assistance, and protection of their resources. They can also provide valuable resources like equipment staging areas and boat launch services. Vermont: https://vtstateparks.com/ . New York: https://parks.ny.gov/parks/.
- Wildlife rehabilitation facilities: There is no mention in the current plan of wildlife capture and rehabilitation resources available in the Champlain Valley. Vermont has a state directory of licensed rehabilitators at: https://vtfishandwildlife.com/sites/fishandwildlife/files/documents/Learn%20More/Living%20with%20Wildlife/Rehabilitation/Wildlife_Rehabilitator_Locator_Map.pdf. For more regionally based wildlife organizations, Tri-State Bird Rescue may be the most qualified resource for New England. https://tristatebird.org/oil-spill-response/.
- New York Drinking Water Intakes: There are no listings of contacts for New York State public drinking water managers. The County Department's of Health are responsible for permitting, but it is not clear who the emergency contacts should be. It is important to have them listed so they can be contacted immediately in the case of a spill in the lake to protect public health.

- Lake Champlain Maritime Museum: The Maritime Museum specializes in underwater historic sites on the lake. The museum organization performs research and exploration and provides education on the history of the lake. They have access to SCUBA diving teams and remotely operated vehicles (ROVs) to help explore the subsurface of the lake. https://www.lcmm.org/
- Vermont and New York State Historic Preservation Officers (SHPO): State SHPO's are closely familiar with historic sites and ongoing research in their state. They can provide important information to ensure the protection of important cultural and historic resources during a spill. Vermont: https://accd.vermont.gov/historic-preservation.

  New York: https://parks.ny.gov/shpo/.

  Quebec: https://www.canada.ca/en/conservation-institute.html.
- Boating Community Contacts: The recreational boating and marina community will be greatly impacted by a spill on the lake. They should be contacted during an incident to keep them informed on the impacted areas of the lake. They could also provide resources to assist the response including vessels, dock space or fueling services. A list of marinas could be helpful to facilitate communications to the boating community. The Vermont Boat & Marine Association has a partial list at https://vtbma.org/. Lake Champlain Sea Grant maintains a listserv of marina owners and operators on the lake (join the list called lakechamplainmarinas at: https://www.uvm.edu/it/mailinglists/) and a smartphone app where all

marinas with sewage pumpouts, and their contact information and hours are available on a map of Lake Champlain (https://www.uvm.edu/seagrant/sewage-pumpout-navigation-app).

Lake Champlain International is an advocacy group for boating and fishing communities: https://www.mychamplain.net/.

REFERENCES

Bazenas, T. (2007, November 22). *Middlebury Train Derailment*. Retrieved from EPA On-Scene Coordinator (OSC) Response WebSite: https://response.epa.gov/site/site_profile.aspx?site_id=3592

Bourguet, L., & Murphy, J. (2018). *Danger on the Tracks: Oil-by-Rail's Threat to Lake Champlain and the Adirondack Region.* Retrieved from National Wildlife Federation: https://www.nwf.org/-/media/Documents/PDFs/NWF-Reports/2018/Danger-on-the-Tracks_2018.ashx

Brotherhood of Locomotive Engineers and Trainmen. (2004, June 4). *Canola Oil Spill in Lake Champlain Nearly Cleaned Up*. Retrieved from Brotherhood of Locomotive Engineers and Trainmen: https://www.ble-t.org/pr/news/headline.asp?id=10647

Canadian Pacific Railway. (2020). *Markets We Serve*. Retrieved from Canadian Pacific Railway: https://www.cpr.ca/en/our-markets

Dedam, K. S. (2007, May 27). *Train derailment causes scare.* Retrieved from Press Republican : https://www.pressrepublican.com/news/local_news/train-derailment-causes-scare/article_b5242fb6-dd8d-5701-838b-9ecc53a7bdd2.html

Federal Railroad Administration Office of Safety Analysis . (2020). *Summary of Train Accidents With Reportable Damage, Casualties, and Major Causes*. Retrieved from Federal Railroad Administration Office of Safety Analysis : https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/TrainAccidentDamage.aspx

International Lake Champlain - Richelieu River Study Board. (2019). *The Causes and Impacts of Past Floods in the Lake Champlain - Richelieu River Basin* . International Joint Commission.

Jensen, J. R., Halls, J. N., & Michel, J. (1998). A Systems Approach to Environmental Sensitivity lndex (ESI) Mapping for Oil Spill Contingency Planning and Response. *Photogrammetric Engineering and Remote Sensing*, 1003-1014.

Kim, T.-H., Yang, C.-S., Oh, J.-H., & Ouchi, K. (2014). *Analysis of the Contribution of Wind Drift Factor to Oil Slick Movement under Strong Tidal Condition: Hebei Spirit Oil Spill Case.* PloS one, 9(1).

Lake Champlain Basin Program. (2006). *The Basin Fact Sheet Series: Number 3* . Grand Isle, VT: The Lake Champlain Basin Program.

Lake Champlain Maritime Museum. (2020, February 23). *Shipwrecks of Lake Champlain*. Retrieved from Lake Champlain Maritime Museum: https://www.lcmm.org/archaeology/shipwrecks/

Lamoureux, J. (1995, March 5). *Press Republican Plattsburgh, NY.* Retrieved from NYS Historic Newspapers: https://nyshistoricnewspapers.org/lccn/sn88074101/1995-03-05/ed-1/seq-4.pdf

LCBP. (2020). *Lake Champlain Basin Program*. Retrieved from Lake Champlain Basin History: https://www.lcbp.org/about-the-basin/history-timeline/

McCormick, M. J., Manley, T. O., Beletsky, D., Foley III, A. J., & Fahnenstiel, G. L. (2008). *Tracking the Surface Flow in Lake Champlain.* J. Great Lakes Res. 34:721–730.

Meyer, G., & Gruendling, G. (1979). *Limnology of Lake Champlain.* Burlington: New England RIver Basins Commision.

NOAA. (2015). *An FOSC's Guide to NOAA Scientific Support.* Seattle, WA: Department of Commerce.

Northwest Area Committee. (2014). *Lake Washington Geographic Response Plan.* Seattle, WA: U.S. Environmental Protection Agency.

Saxton, R. (2020, February 27). *Oil By Rail: Lake Champlain & Hudson River Region* . Retrieved from National Wildlife Federation: https://www.nwf.org/~/media/PDFs/Global-Warming/ChamplainOilbyRail_QuickFacts.ashx

Sergy, G. A., & Owens, E. H. (2011). *Differences and similarities in Freshwater and Marine Shoreline Oil Spill Response.* 2011 International Oil Spill Conference.

Stepenuck, K. (2017). *Lake Champlain Marina Education Needs*. Burlington, VT: Lake Champlain Sea Grant.

The University of Rhode Island. (2020, February 26). *Scientific Support for Emergency Environmental Incidents*. Retrieved from The University of Rode Island Coastal Institute: https://ci.uri.edu/intitiatives/ongoing-initiatives/sseer/

U.S. DOT. (2008). *Traffic Incident Management in Hazardous Materials spills in Incident Clearance.* Washington D.C.: U.S. Department of Transportation Federal Highway Administration. Retrieved from U.S. Department of Transportation Federal Highway Administration.

U.S. EPA. (2018). *Area Contingency Planning (ACP) Handbook Version 2.0.* Washington D.C.: United States Environmental Protection Agency.

U.S. EPA. (2020). *National Priorities List and Superfund Alternative Approach Sites*. Retrieved from United States Environmental Protection Agency: https://www.epa.gov/superfund/search-superfund-sites-where-you-live

U.S. EPA New England. (2005). *Marina Environmental Management Plan.* Boston, MA: United States Environmental Protection Agency New England.

US Environmental Protection Agency . (1992). *Inland Oil Spills.* Washington, D.C.: US Environmental Protection Agency . Retrieved from https://nepis.epa.gov/Exe/ZyNET.exe/2001723X.txt?ZyActionD=ZyDocument&Client=EPA&Index=2000%20Thru%202005&Docs=&Query=%28lake%20champlain%29%20OR%20FNAME%3D%222001723X.txt%22%20AND%20FNAME%3D%222001723X.txt%22&Time=&EndTime=&SearchMethod=1&TocRestrict=n&T

Vermont Rail System. (2020). Retrieved from Vermont Rail System: http://www.vermontrailway.com/index.html

Voigt, B., Lees, J., & Erickson, J. (2015). *An Assessment of the Economic Value of Clean Water in the Lake.* Grand Isle, VT: Lake Champlain Basin Program.

Weston Solutions Inc. (2013). *Multi-Agency Contingency Plan for Emergency Environmental Incidents in the Lake Champlain Region.* Boston, MA: U.S. Environmental Protection Agency.

Winslow, M. (2008). *Lake Champlain A Natural History.* Burlington, VT: Lake Champlian Committee.

Winslow, M. (2010, April). *Lake Look: The Tugboat McAllister*. Retrieved from Lake Champlain Commitee : https://www.lakechamplaincommittee.org/learn/lake-look/tugboat-mcallister/

Young, C. (2005). *Lake Champlain Oil Spill*. Retrieved from EPA On-Scene Coordinator (OSC) Response WebSite: https://response.epa.gov/site/site_profile.aspx?site_id=1477

APPENDIX A: SURVEY QUESTIONS

Lake Champlain Scientific Support Network

Information Survey

Purpose

This study is being conducted by the University of Vermont to gather information about important scientific expertise, information and equipment that would be valuable to an Incident Management Team during the response to an oil spill or natural disaster affecting **Lake Champlain**. The information provided in this survey will be used to assemble a database of scientific support resources that may be accessed by responders during an incident. The database will include names, organizations, contact information, and available expertise or capabilities. This list will be published on Lake Champlain Sea Grant website hosted through the University of Vermont.

1. What scientific expertise would you want available to the Incident Management Team to assist in decisions on **collection and containment strategies** (e.g., GIS specialist, FAA-certified drone pilot)?

2. What scientific information would you want available to the Incident Management Team to assist in decisions on **collection and containment strategies** (e.g., GIS maps, ice cover maps, real time localized weather)?

3. What scientific expertise would you want available to the Incident Management Team to assist in decisions on **environmental protection** (e.g., limnologist, hydrogeologist)?

4. What scientific information would you want available to the Incident Management Team to assist in decisions on **environmental protection** (e.g., sensitive habitat maps, geologic shoreline surveys)?

5. What scientific expertise would you want available to the Incident Management Team to assist in decisions on **wildlife management** (e.g., fisheries biologist, ornithologist, wildlife refuge staff)?

6. What scientific information would you want available to the Incident Management Team to assist in decisions on **wildlife management** (e.g., Wildlife Management Area resource maps, list of locations and contact information for rehabilitation facilities)?

7. What scientific expertise would you want available to the Incident Management Team to assist in decisions on **human health** (e.g., public health specialist, drinking water plant directors)?

8. What scientific information would you want available to the Incident Management Team to assist in decisions on **human health** (e.g., list and locations of drinking water intakes, local water quality monitoring data)?

9. What scientific equipment would be useful for the response that may not be readily available through the government, contractors or the Responsible Party (e.g., drones, research vessels, lab space)?

10. Are there any other scientific or academic resources that you would value during a spill or disaster response in the Lake Champlain Basin (e.g., citizen science volunteers, bird watchers, engineers)?

APPENDIX B: SURVEY RESULTS

Lake Champlain Scientific Support Network

Survey Results

Total Participants: 15

Q1 - What scientific information would you want available to the Incident Management Team to assist in decisions on collection and containment strategies (e.g., GIS maps, ice cover maps, real time localized weather)?

Count	Requested Resource
9	GIS maps
9	Real time/localized weather
6	Ice cover maps
6	Environmental data
6	Spilled product specifications/clean up tools
4	Satellite imagery/aerial photos
4	Cultural/historical data
3	Circulation map
2	Digitized Geographic Response Plans
2	Spill models/trajectory
2	Air quality
2	Water quality
1	Seasonal concerns
1	Endangered species
1	Site specific geology/ hydrology
1	Charts with depth
1	Waste management
1	Water intakes

Q2 - What scientific expertise would you want available to the Incident Management Team to assist in decisions on collection and containment strategies (e.g., GIS specialist, FAA-certified drone pilot)?

Count	Requested Resource
7	High resolution imagery processor/GIS specialist
7	Drone pilot
5	Oil spill equipment/response specialist
4	Air monitoring
3	Fate and effects/trajectory
3	NOAA Scientific Support Coordinator
2	Scientific/environmental tradeoff specialist
2	Public health
2	Drinking water specialist
2	Local currents
1	Historical preservation specialist

1	Field environmental lab
1	ROV operator
1	Current use information
1	Shoreline assessment expertise

Q3 - What scientific information would you want available to the Incident Management Team to assist in decisions on environmental protection (e.g., sensitive habitat maps, geologic shoreline surveys)?

Count	Requested Resource
12	Sensitive habitat map
5	Shoreline surveys
4	Endangered/sensitive species
3	Surface current/circulation maps
3	Water intake locations
2	Migratory bird information
2	Geographic response plans
2	Bathymetry maps
1	Health risk assessments
1	Contaminant information
1	Water quality/sampling
1	Lake levels/gauge readings
1	State Historic Preservation Officers

Q4 - What scientific expertise would you want available to the Incident Management Team to assist in decisions on environmental protection (e.g., limnologist, hydrogeologist)?

Count	Requested Resource
8	Fish and game biologist/warden
4	Hydrogeologist/geologist
3	Plume modelers/ oil fate
3	Limnologist
2	Environmental sampling expert
1	Biologist
1	Ecologist
1	Cultural/historical experts
1	Public health expert
1	Archaeologist
1	Meteorologist
1	NOAA SSC
1	Surface water flow maps including all tributaries
1	USEPA ERT oil response specialist

Q5 - What scientific information would you want available to the Incident Management Team to assist in decisions on wildlife management (e.g., Wildlife Management Area resource maps, list of locations and contact information for rehabilitation facilities)?

Count	Requested Resource
6	ESI/habitat maps
5	Wildlife rehab facilities
5	Endangered/threatened species
5	Real time wildlife population data including migration patterns
3	Migratory bird information
2	List of wildlife resources
2	Resource managers
1	Wildlife transporters
1	Fisheries information

Q6 - What scientific expertise would you want available to the Incident Management Team to assist in decisions on wildlife management (e.g., fisheries biologist, ornithologist, wildlife refuge staff)?

Count	Requested Resource
10	Fish and wildlife experts
6	Bird specialist
5	Fisheries biologist
3	Biologist
3	Wildlife rescue specialists
3	Wildlife refuge staff
2	DEC resource managers
1	Boats/operators
1	Federal, state, local and non-profit perspective
1	NOAA SSC
1	Environmental conservation officers
1	Tri-State Bird Rescue
1	Water quality sampling experts

Q7 - What scientific information would you want available to the Incident Management Team to assist in decisions on human health (e.g., list and locations of drinking water intakes, local water quality monitoring data)?

Count	Requested Resource
11	Drinking water intakes
6	Public health impacts/sensitive populations
5	Local water quality monitoring
5	Air monitoring information
3	Public access areas
3	Contaminant info
1	Fisheries information
1	Wind/weather
1	Plume modeling
1	Real time monitoring of impacted media
1	Industrial intakes
1	Risk communication specialist

Q8 - What scientific expertise would you want available to the Incident Management Team to assist in decisions on human health (e.g., public health specialist, drinking water plant directors)?

Count	Requested Resource
8	Public health specialist
5	Drinking water expert
2	ATSDR regional representative
2	Local fire department/hazmat team
1	Toxicologist
1	Plume modelers
1	Air quality assessment
1	Fisheries staff
1	Local park/ beach staff
1	Field lab

Q9 - What scientific equipment would be useful for the response that may not be readily available through the government, contractors or the Responsible Party (e.g., drones, research vessels, lab space)?

Count	Requested Resource
7	Drones
4	Aircraft
3	Air monitoring equipment
2	Vessels/boats
2	Sampling equipment
2	Lab space
1	Mobile lab
1	People with local knowledge
1	Waste disposal
1	Oil fingerprinting

Q10 - Are there any other scientific or academic resources that you would value during a spill or disaster response in the Lake Champlain Basin (e.g., citizen science volunteers, bird watchers, engineers)?

Count	Requested Resource
4	Volunteer management
3	Bird watchers
2	Habitat data
1	Fish and wildlife experts
1	Local environmental groups
1	Shoreline Cleanup and Assessment (SCAT) trained personnel
1	Engineers
1	Cultural resources
1	Incident command post location
1	Tribes
1	Tri-State Bird Rescue
1	University of Vermont
1	Sunken historic resources
1	Water circulation and scale
1	Lakes conditions pre-spill
1	Boating community