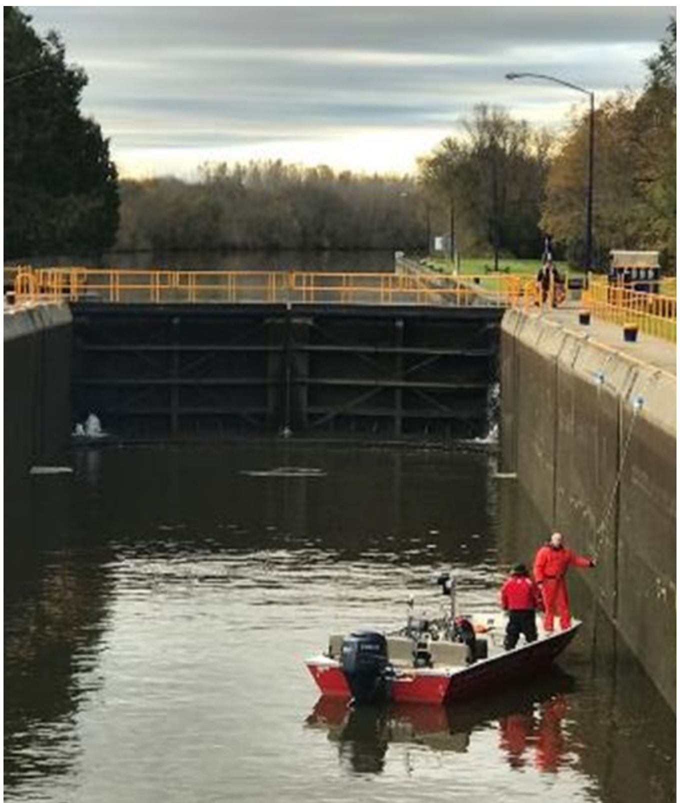
US Army Corps of Engineers
New York District

Lake Champlain Basin Program

NEIWPCC



Champlain Canal Aquatic Invasive Species Barrier Study Phase I Report

USACE, New York District

Princeton Hydro, LLC

HDR

Date: March 2022

New England Interstate Water Pollution Control Commission
Lake Champlain Basin Program
New York State Canal Corporation
New York State Department of Environmental Conservation
Vermont Agency of Natural Resources
United States Fish & Wildlife Service

Executive Summary

Objectives of the Champlain Canal Aquatic Invasive Species Barrier Study

This Report is an informative document detailing the relevant engineering, economic, and environmental factors necessary for selecting a feasible barrier to prevent Aquatic Nonnative Species (ANS) from transporting between the Hudson River Basin and the Lake Champlain Basin via the Champlain Canal. It was prepared to meet the following objectives:

- Prevent the transfer of ANS between the Hudson River Basin and Lake Champlain Basin
- Have a favorable cost to benefit ratio
- Be an environmentally acceptable solution that takes into account the requirements and desires of the many stakeholder groups along the canal

The study area of this report focused on the summit canal located between Lock C8 to the south and Lock C9 to the north, along with adjacent functional elements, such as the Glens Falls Feeder Canal. This Report reviews the process for defining the study area, documents the existing conditions, summarizes the operational history and use of the canal, discusses existing aquatic habitat and conditions, identifies ten treatment measures, provides an analysis of six alternatives which are comprised of combining the various treatment measures, projected cost estimates for the three tentatively selected alternatives, and ultimately defines the preferred alternative plan.

Authorizing Legislation

This study was authorized under Water Resources Development Act of 2000 (WRDA 2000), Section 542, which authorized the Secretary of the Army to establish a program for providing environmental assistance to non-federal interests in the Lake Champlain Watershed.

Report Content

Chapters 1 and 2, Introduction and Existing Conditions provides a summary of the authorizing language, the study goals and objectives, followed by a review of the existing conditions in the study area. The Existing Conditions Analysis provides an overview of facilities in the study area, a list of current and potential stakeholders, historically sensitive canal features, prior studies conducted, the physical operation and layout of the Hudson/Champlain canal system, the natural watershed boundaries and how they have been modified by, or interact with the canal system, and an extensive inventory of the nonnative and invasive species within the canal and connected bodies of water that will be targeted for control. Chapter 3 Plan Formulation, includes the development of the ten treatment control measures and groups these measures into a set of six Alternative Plans which considered multiple physical, chemical and or operational modifications to the canal system that could accomplish the dispersal barrier on the Champlain Canal to prevent the spread of aquatic invasive species between the Hudson and Champlain watersheds. Chapter 4 Plan Evaluation, includes the results of a Multi-Criteria Decision Analysis (MCDA) which selected three preferred alternatives from the original set of six. This section of the report also provides conceptual plans, the preliminary construction cost estimates with a more detailed set of plans on the three preferred alternatives, followed by a Cost-Effectiveness and Incremental

Cost Analysis (CEICA) for the top three plans. Chapter 5 Recommended Plan identifies Alternative 2 Physical Barrier Plan as the Recommended Plan. The final section of the report, Chapter 6 Next Steps lays out two paths for the completion of the future studies, design, and construction of the selected project. The two options for completing this work would be; 1) to follow the current path under WRDA 2000, Section 542 “The Lake Champlain Program” or 2) utilize the newer program under WRDA 2007, Section 5146 which provides for construction to be 100% federally-funded, however, federal funds have not been appropriated for this authority.

Project Description

The Recommended Plan includes several measures to limit the transfer of ANS including, a physical barrier across the canal, cutting off the flow between locks C9-C8, a large boat lift, a small boat ramp and cleaning station located north of the Glens Falls Feeder Canal and repairing the lock seals.

To prevent ANS from traversing between the Hudson River and Lake Champlain watersheds the recommended plan includes constructing a berm north of the Glens Falls Feeder Canal. This alternative also includes a cleaning station and a boat lift where small and large boats would be cleaned prior to being placed back in the water on the other side. This wash water would be captured and stored to be sent to a treatment plant. This alternative provides the most effective protection from ANS crossing between the Hudson River and Lake Champlain Watersheds, but it does remove the possibility of large commercial barges travelling the full length of the canal. A loading/offloading facility would be required if commercial shipping were to be continued along the canal, which was not fully evaluated as part of this study.

Estimated Cost of Construction

Subsequent to the selection of the top three plans through the MCDA process, rough order of magnitude construction costs were developed for the top three plans. The rough order of magnitude construction cost includes expenditures for construction of the project, including engineering, contingency, permitting, soil erosion controls, construction inspection, and construction management. The estimated cost of the Recommended Plan is $18,245,000 for the year 2022. Due to the uncertainty of the future date of construction, cost were computed for today’s rates as they are only being used for the completion of the CEICA process in selecting the recommended plan from the three preferred alternatives.

Conclusion & Recommendation

This Report concludes that the Alternative 2 Physical Barrier Plan provides the most effective method for preventing the transfer of ANS between the Lake Champlain and Hudson River Watersheds, is supported by cost benefit analysis, and provides for continuing most vessel travel along the canal. This recommendation is based on the study detailed in the following pages and will be subject to feasibility-level analysis prior to design and construction.

Refer to Figure 1 below for a depiction of the Alternative 2 plan, greater level of detail drawings can be found in Appendix F – Preferred Alternative Concept Plan Layouts.

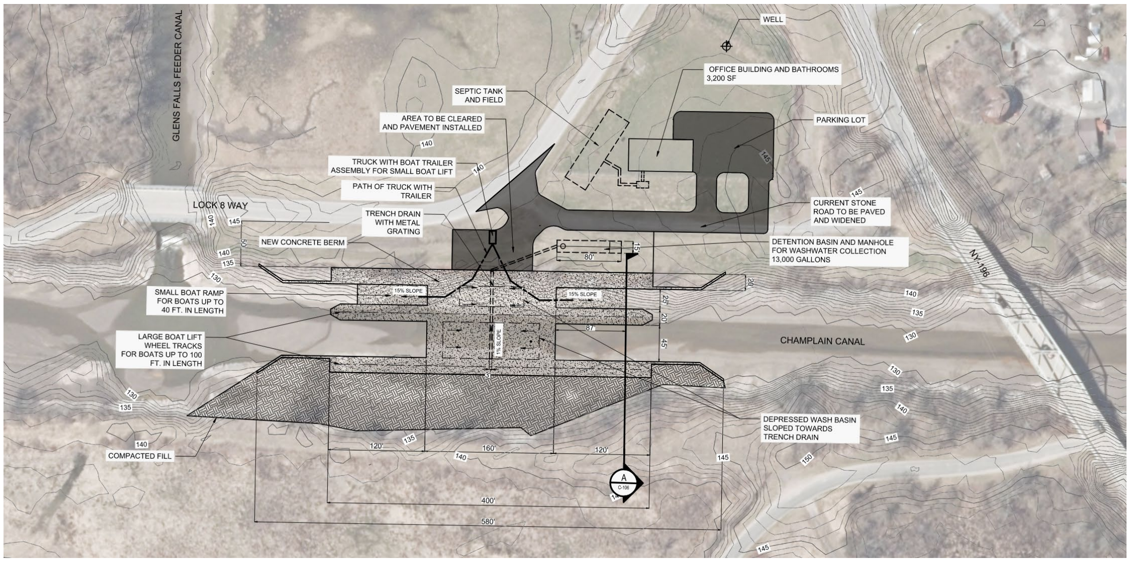


Figure 1. Alternative 2 General Layout Plan.

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Acronyms

AIS	Aquatic Invasive Species
ANS	Aquatic Non-native Species
CAWS	Chicago Area Waterway System
CE/ICA	Cost Effectiveness / Incremental Cost Analysis
EPA	Environmental Protection Agency
ER	Engineering Regulation
ERDC	Engineering Research and Development Center
Ft. (ft.)	Feet
FWOP	Future Without Project
GLMRIS	Great Lakes and Mississippi River Interbasin Study
GMP	General Management Plan
HDR	Henningson, Durham & Richardson
In.	inches
IWR	Institute for Water Resources
LCBP	Lake Champlain Basin Program
MCDA	Multi-Criteria Decision Analysis
MGD	Million Gallons per Day
N/A	Not Applicable
NACCS	North Atlantic Coast Comprehensive Study
NAVD88	North American Vertical Datum of 1988
NEIWPCC	New England Interstate Water Pollution Control Commission
NPS	National Park Service
NY	New York
NYPA	New York Power Authority
NYSCC	New York State Canal Corporation
NYSDEC	New York State Department of Environmental Conservation
PDT	Project Delivery Team
PE	Professional Engineer
PH	Princeton Hydro, LLC
PMP	Project Management Plan
RFP	Request for Proposals
Sq. mi	square miles
USACE NYD	United States Army Corps of Engineers, New York District
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VTANR	Vermont Agency of Natural Resources
WRDA	Water Resources Development Act

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1 Introduction

1.1 Introduction

This report documents the results of the Champlain Canal Aquatic Invasive Species Barrier Study conducted by the U.S. Army Corps of Engineers, New York District. The non-federal sponsor for the project is the New England Interstate Water Pollution Control Commission (NEIWPCC).

Aquatic nonnative species (ANS) and invasive species in the Hudson River pose a threat to Lake Champlain. A dispersal barrier in the Champlain Canal, which connects the Hudson River to Lake Champlain, could prevent multi-taxa biological traffic including fish, plants, plankton, invertebrates, and pathogens, from reaching the lake.

This report provides information about existing conditions in the study area, including prior studies; potential and current stakeholders; facilities; historically sensitive canal features; the physical operation and layout of the Hudson/Champlain canal system; natural watershed boundaries and how they have been modified by, or interact with, the canal system; and an extensive inventory of the nonnative and invasive species within the canal system and connected waterways to target for control.

The report describes the process that was used to formulate, evaluate, and compare alternatives to meet the planning objectives and avoid violating planning constraints. A Multi-Criteria Decision Analysis (MCDA) and Cost Effectiveness and Incremental Cost Analysis (CEICA) were used to select three preferred alternatives from the original set of six, and finally, to identify a recommended plan. The recommended plan would effectively reduce the spread of nonnative and invasive species, have a favorable cost-to-benefit ratio, and be an environmentally acceptable solution that considers the requirements and desires of the many stakeholder groups along the canal.

1.2 USACE Planning Process

This study followed the six-step planning process outlined in the 1983 Principles and Guidelines for Water and Land Related Resources Implementation Studies and Engineering Regulation (ER) 1105-2-100, the Planning Guidance Notebook. The six steps are as follows:

1. Specify problems and opportunities.
2. Inventory and forecast conditions.
3. Formulate alternative plans.
4. Evaluate effects of alternative plans.
5. Compare alternative plans.
6. Select recommended plan.

National Environmental Policy Act (NEPA) processes will be included in a subsequent study phase.

1.3 Study Authority

In December 2000, Public Law #106-541, the Water Resources Development Act of 2000 (WRDA 2000) was signed by the President. Section 542 of WRDA 2000 authorized the Secretary of the Army to establish a program for providing environmental assistance to non-federal interests in the Lake Champlain watershed. It defines the Lake Champlain watershed as the land areas within Addison, Bennington, Caledonia, Chittenden, Franklin, Grand Isle, Lamoille, Orange, Orleans, Rutland, and Washington Counties in the State of Vermont; the land areas that drain into Lake Champlain and that are located within Essex, Clinton, Franklin, Warren, and Washington Counties in the State of New York; and the near-shore areas of Lake Champlain within the counties referred to in New York. Refer to **Appendix A** for a full copy of the authorizing language.

The Champlain Canal Invasive Species Barrier Study was conducted under the WRDA 2000, Section 542 program authority.

1.4 WRDA 2000, Section 542 Program Summary – Lake Champlain Watershed

The goal of the Lake Champlain Watershed Environmental Assistance Program as authorized by WRDA 2000, Section 542 is to provide assistance with the planning, design and construction of projects that contribute to the protection and enhancement of the water quality, water supply, ecosystem and other water related issues within the Lake Champlain watershed.

Lake Champlain has a surface area of 435 square miles. The watershed draining into the lake covers 8,234 square miles in New York, Vermont, and Quebec. There are 11 major tributaries draining into the lake, ranging from 20 miles to 102 miles in stream length.

A General Management Plan (GMP) that USACE prepared in cooperation with the Lake Champlain Basin Program (LCBP) serves as the framework for implementing the program. The GMP outlines the process through which critical restoration projects in the Lake Champlain watershed are identified, prioritized, and implemented.

The LCBP is the lead organization in coordinating with USACE for this program. The Lake Champlain Steering Committee is responsible for overseeing activities of the LCBP. Its members include representatives from New York and Vermont state agencies, other federal agencies including the Department of the Interior, Department of Agriculture, and Environmental Protection Agency, citizen representatives, and local government representatives. The LCBP, through the Steering Committee, develops Section 542 program goals and proposed project screening methodology, identifies priority projects, and develops project eligibility criteria.

1.5 Study Area

The study area includes the Hudson/Champlain canal system and connected waterways. The study focuses on the Champlain Canal between Locks C7 (Fort Edward) and C9 (Fort Ann), which includes Dunham and Smith basins (see Figure 1, where locks are shown as the black numbers 8 and 9). It is through this section of the canal that water transfers from the Hudson River into Lake Champlain.

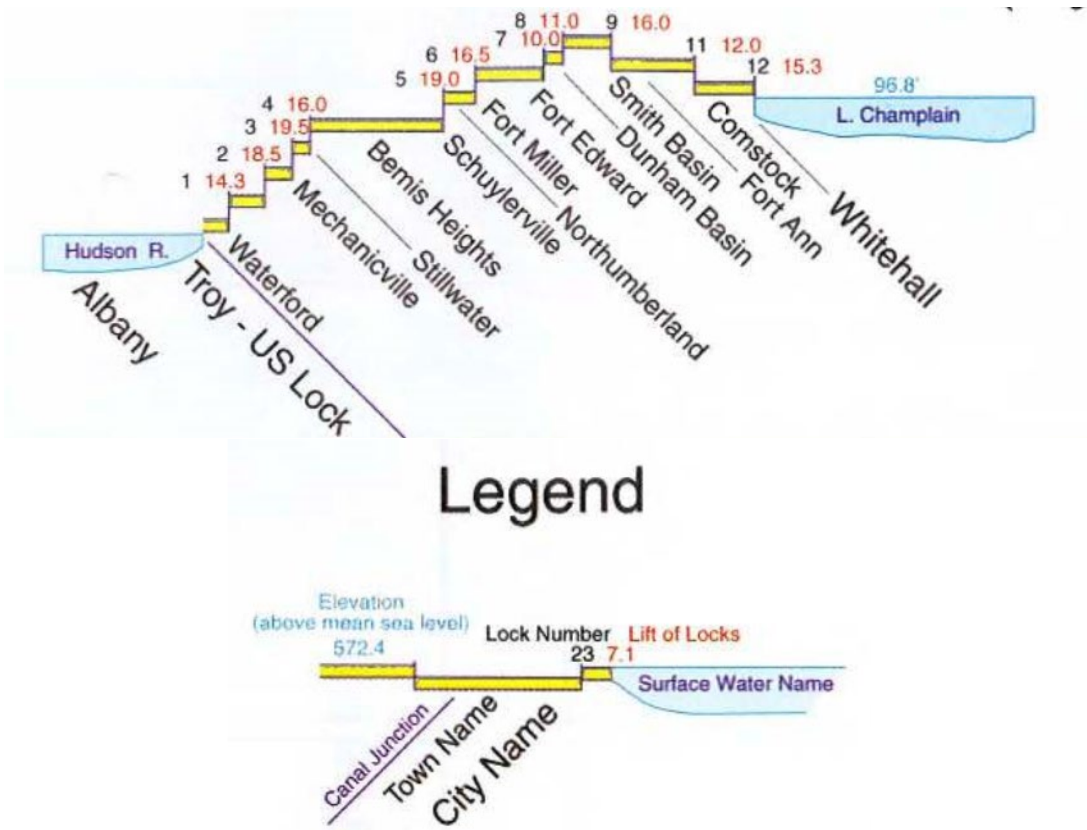


Figure 2. Champlain Canal Lock Profile

http://www.canals.ny.gov/navinfo/charts/mileage.jpg

The Glens Falls Feeder Canal brings water from the Hudson River to the summit of the Champlain Canal between Locks C8 and C9. Refer to **Appendix B** - Plans of Record for copies of record drawings of the prominent physical infrastructure of the canal system. Many of these drawings date back to the 1920s. During the canal navigation season, generally between May 1st and November 15th, the Glens Falls Feeder Canal maintains water levels for navigability between Lock C7 (Fort Edward) and Lock C12 (Whitehall). A barrier to prevent aquatic nonnative and invasive species would be most effective along the canal reach located between the Glens Falls Feeder Canal and Lock C9 as it connects these two major water systems. The canal system north of Lock C9 is not the focus of this report, although maintaining vessel passage to Lake Champlain is a primary consideration.

1.6 Purpose and Need

The purpose of the Champlain Canal Invasive Species Barrier Study is to compare the costs, benefits, and effectiveness of different management alternatives that could accomplish hydrological separation of the Lake Champlain drainage from the Hudson River drainage system. The LCBP, NEIWPCC, and partner agencies have provided staff to help facilitate the study and plan formulation effort. The assisting agencies include the New York State Canal Corporation (NYSCC), New York State Department of Environmental Conservation (NYSDEC), Vermont Agency of Natural Resources (VTANR), United States Fish and Wildlife Service (USFWS), Lake Champlain Sea Grant (LCSG) and others. This study addresses one of the main goals of the LCBP's Opportunities for Action:

> ***"Prevent the introduction, limit the spread, and control the impact of non-native aquatic invasive species in order to preserve the integrity of the Lake Champlain ecosystem."***

The LCBP, NYSCC, NYSDEC, VTANR, USFWS, LCSG, and others have been working in partnership for over 15 years to engage stakeholders in a discussion about preventing the spread of aquatic nonnative and invasive species through the Champlain Canal. The consensus of those consulted was to pursue a planning study (US Army Corps of Engineers and Other Agencies, 2014) and in 2009 the NYSCC wrote a letter to the USACE requesting that the Champlain Canal Dispersal Barrier Feasibility Project be initiated, refer to Appendix A for NYSCC letter of support. This study will meet the LCBP, NYSCC and partners' shared needs.

1.7 Problems and Opportunities

The Lake Champlain Watershed covers Lake Champlain (435 square miles in surface area) and the 11 major tributary watersheds draining into the lake covering 8,234 square miles in New York, Vermont, and Quebec. Aquatic invasive species (AIS) present in the surrounding Great Lakes, Erie Canal, and Hudson River (e.g., hydrilla, round goby, Asian clam, quagga mussel, Asian carp, and snakehead) are a threat to Lake Champlain because of their potential movement from the Hudson River or the Great Lakes through the Erie Canal to Lake Champlain and the economic and ecological impacts they may cause. Similarly, there are or may be species in Lake Champlain that are not native to the surrounding Hudson River, St. Lawrence River and Great Lakes basins; currently, at least 12 of those 51 species are officially classified as "invasive" in the Lake. With this as an example, if a new AIS becomes established in Lake Champlain it could spread to those basins; also, species native to the lake may be accidentally transported out to other systems where they are non-native. There are opportunities to prevent the inter-basin transfer of aquatic nonnative and invasive species between the Hudson River and Lake Champlain, by implementing a barrier system in the Champlain Canal.

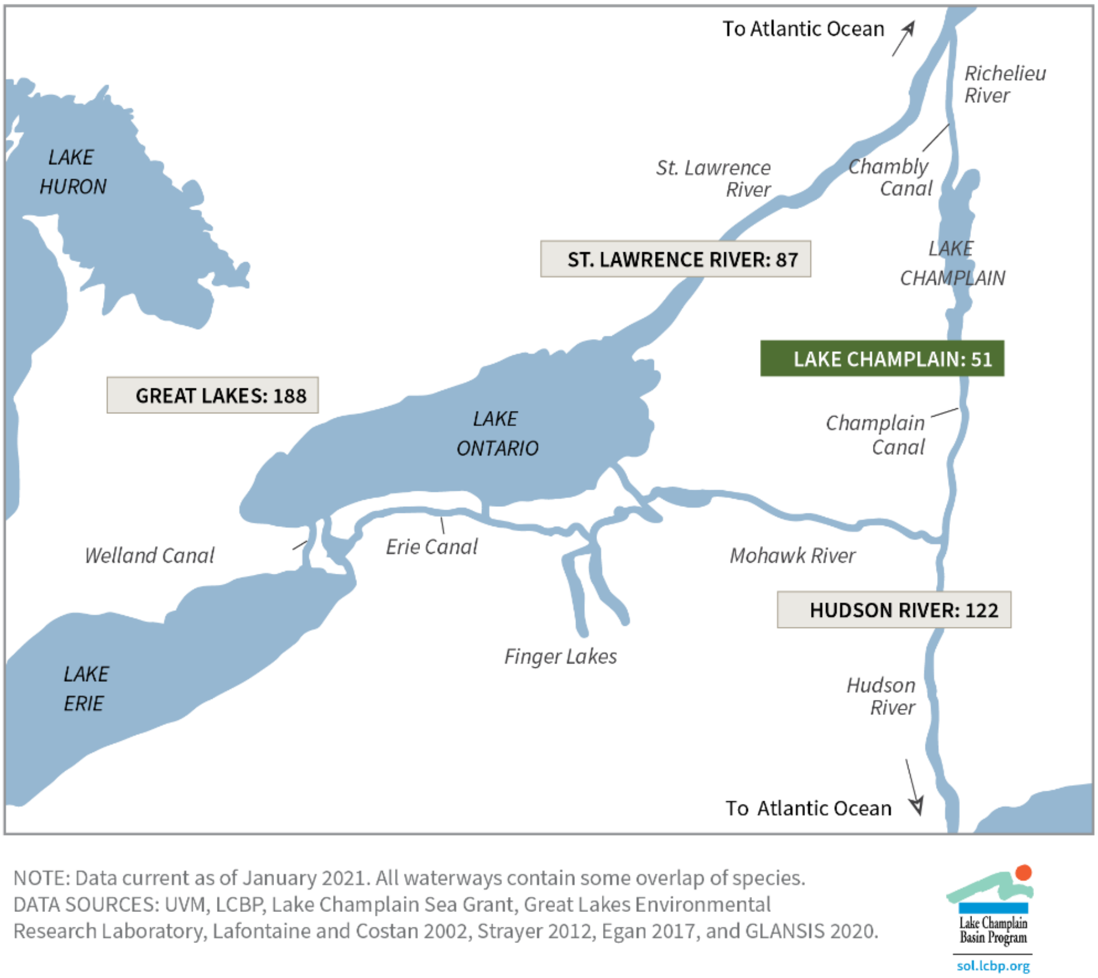


Figure 3. Non-native threats to Lake Champlain Basin from connected waterways (LCBP, 2021)

1.8 Objectives and Constraints

The planning objective, or the desired effect of alternative plans developed in this study, is to:

- Reduce or prevent the introduction and spread of aquatic nonnative and invasive species through the Champlain Canal.

Constraints that limit the planning process for this study include that those alternative plans must:

1. Maintain a viable navigable connection for commercial and recreational vessel traffic between Lake Champlain and the Hudson River.
2. Maintain the Champlain Canal as an important catalyst for economic and

ecological growth and tourism in the region.

3. Continue to support non-navigation benefits of the continued operation of the Champlain Canal to the region and to the States.

Other planning considerations for this study that will ensure alternative plans are acceptable to the larger stakeholder community and optimize the investment of funds include that plans:

1. Preserve the historic features of the existing canal infrastructure.
2. Avoid or minimize the need to acquire new real estate rights.
3. Enhance recreational and educational opportunities along the Champlain Canal.
4. Minimize the additional operations, maintenance, repair, replacement, and rehabilitation costs attributed to any new infrastructure.

The NYSCC has indicated they are obligated to provide unobstructed passage for commercial and maintenance vessels. They also noted that they are not obligated to provide flow to the hydropower facility along the canal. These constraints may be further evaluated during future phases of design.

1.9 Study Scope

Because the number and diversity of species that could use the Champlain Canal as a vector are so great, physical, mechanical, and chemical treatment modifications that would accomplish hydrological separation were considered in this study. Behavioral, biological, and water quality barriers were not considered, as limited by the scope of this project.

2 Existing and Future Without Project Conditions


Headwaters of Feeder Canal at Glens Falls, NY

This section summarizes the existing conditions used to establish the baseline for the physical canal system works, vessel traffic volumes, present aquatic nonnative, and invasive species populations and what the vectors of migration are to determine potential hydrologic barrier alternatives. Continuing the benefits of canal navigation on social, economic, and environmental resources of the Champlain Canal and the Lake Champlain drainage basin are also central to alternative formulation. Various vectors of migration through the canal include taxa that can swim independently, crawl or walk along the substrate, attach to, or be transported within vessels, or float with the current.

Baseline and future ecosystem studies discussions will focus on the canal operations and the aquatic nonnative invasive species. The forecast of the future without-project condition reflects the conditions expected during a 50-year period of analysis and constitutes the benchmark against which plans are evaluated.

Review of the existing records and a field reconnaissance visit have been conducted to assist in determining the following existing conditions:

1. Inventory of waterway facilities in the study area.
2. Review of statute, regulations and policies governing the operation of the canal.
3. Review of historical operational use of the canal, seasonally and annually, including types, sizes, and weights of vessels and the frequency of use by type in the study area.
4. Stakeholders within the Lake Champlain Basin and the Champlain Canal with interest in the canal's current and future operation and identification of current and anticipated needs of these stakeholders.
5. Locations of historical sensitivity in the study area.
6. Canal infrastructure needs anticipated, including repairs, maintenance, and restoration.
7. Environmental conditions, with a focus on the existing aquatic habitat.

A species inventory has been compiled to give a more complete picture of the Champlain Canal and surrounding area ecosystems and to aid in evaluating alternatives for AIS exclusion. Information contained in the species inventory was sourced from UVM and

Lake Champlain Sea Grant, LCBP, NYSCC, and other Champlain Canal documentation and includes:

1. An inventory of all known aquatic nonnative and invasive species that currently use or have been known to exist in the Champlain Canal between the Hudson River and Lake Champlain

2. Documentation of native, rare, threatened, and endangered species, as well as aquatic nonnative and invasive species in the Hudson River and Great Lakes, and

3. An assessment of aquatic nonnative and invasive species in these waters that are likely to come to the Champlain Canal via the Erie and determination of the target species that pose an ecosystem and socioeconomic threat.

Refer to **Appendix B** – Aquatic Nonnative and Invasive Species Inventory Report and Matrix for a summary of the species known to exist in the surrounding waterways, the likely modes of transport through the canal system and the severity of the threat risk to Lake Champlain.

2.1 Inventory of Waterway Facilities

The Champlain Canal extends approximately 60 miles and connects the Hudson River (south) to Lake Champlain (north). There are a total of 11 operational locks along the system. The locks of interest to this study are C8 and C9, which are at the highest elevation along the system. The summit canal between locks C8 and C9 represents the canal zone with the greatest potential for mixture of flows from both watersheds and therefore is also the reach where the greatest opportunity exists to separate these flow paths. Refer to **Figure 4** below for the lock system profile showing the elevations along each canal reach. The system includes over 120 ft. of elevation change.

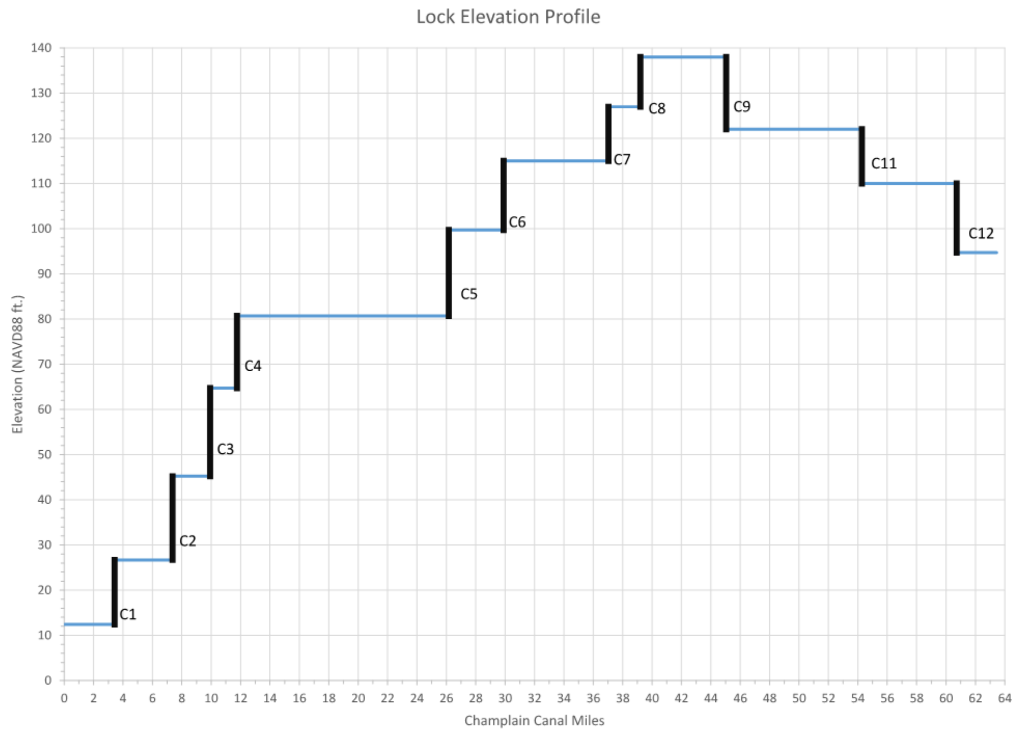


Figure 4. Champlain Canal Lock Elevation Profile

2.1.1 Canal Locks

The minimum depth along the canal is 12 ft. The canal channel is generally unlined with a natural bottom surface. Its typical width is 200 ft. and where encroachments exist, such as bridges, docks, guard gates, and marinas, the width reduces to a minimum of 45 ft. (New York State Canal Corporation, 2017). **Table 1** below provides information regarding lock dimensions, lift, and volume for C9, C8 and C7, which are the focus of this study:

Table 1. Champlain Canal Summary of Lock Configuration

Lock	Width, ft.	Length, ft.	Lift[1], ft.	Upper Pool Elevation, NAVD88	Approx. Vol. of water at Upper Pool, gallons.	Type of Gate Operation
C9	45	330	16	138.0	1,777,248	Hydraulic
C8	45	330	11	138.0	1,221,858	Mechanical
C7	45	330	10	127.0	1,110,780	Mechanical

[1] *The lift is the height of water which the canal fluctuates between in order to allow vessel traffic through the lock*

Figure 5 and **Figure 6** below are depictions of the Champlain Canal Lock C8, profile and plan views from the plans of record, dating back to the 1920s. For a complete view of the plans of record refer to **Appendix B1**.

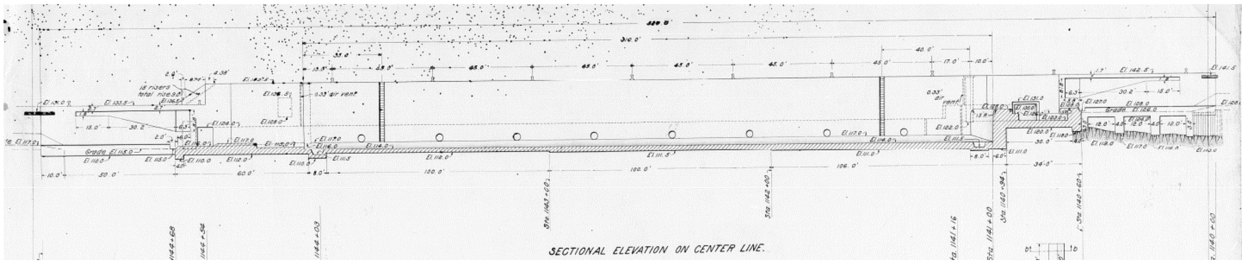


Figure 5. Champlain Canal Lock C8 Sectional Elevation (Profile View)

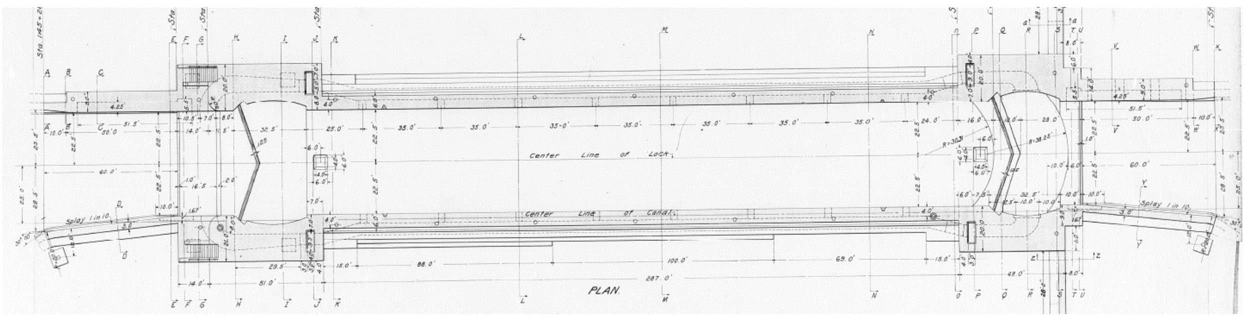


Figure 6. Champlain Canal Lock C8 Plan

2.1.2 Lock C8

Located in Fort Edward, NY approximately 2 miles south of NYS Route 196 bridge over the canal, the lock controls house is situated on the northwest bank of the canal. The closure structure at Lock C8 is operated by a mechanical gate system. There is a historic water wheel located on the northwest side of the lock which is no longer in use and dates back to the early 1900s when the canal was constructed (Refer to **Appendix B3** for additional details). This water wheel was once used to generate electricity. There is an existing bypass culvert adjacent to the water wheel which can allow water to discharge downstream of the lock gates between locks C8 and C7. This bypass culvert is valve-controlled and is normally closed. When open, it discharges to an unnamed tributary that flows into the canal south of Lock C8.

2.1.3 Lock C9


Spillway Dam at Lock C9

Located in Fort Ann, NY just south of NYS Route 149 bridge over the canal, the lock control house is situated on the west bank of the canal. The closure structure at Lock C9 has an updated hydraulic gate operation system. During navigation season, excess water from the C8/C9 canal discharges over a spillway located on the east bank of the canal into Wood Creek. Wood Creek flows north to its confluence with the Champlain Canal into the Champlain drainage basin, just north of Lock C9. The volume of excess daily feed water that passes over the spillway far exceeds the volume of water that passes north towards Lake Champlain due to lock passages. The spillway structure allows for an unobstructed flow of water from the Hudson River, along the Feeder Canal, thence north along the C8/C9 canal to continue its flow northward towards Lake Champlain.

2.1.4 Glens Falls Feeder Canal

The Champlain Canal's main source of feed water is the Glens Falls Feeder Canal, a diversion of the Hudson River flows. Water is diverted from the Hudson River at Glens Falls, NY and flows to Bond Creek via the Old Champlain Canal. The Glens Falls Feeder Canal provides water between Locks C8 and C9 (forming the Smith Basin). Plans, sections, and details of the Feeder Canal are included in **Appendix B2**. When a vessel passes through Lock C8, the water exchanged will be composed primarily of Hudson River basin water, and discharge back towards the Hudson River basin itself. During Lock C9 operations, for vessels traveling in either direction (northbound or southbound), lockage water drawn from the C8/C9 canal always drains north to the Lake Champlain basin. The water exchanged during the Lock C9 passage is composed primarily of Hudson River basin water. Water from Lock C9 empties north of the gates into the Lake Champlain basin. The locks are filled by gravity via 6 ft. wide by 8 ft. high box culverts along both sides of the lock.


Truss Bridge over Feeder Canal at Lock 8 Way

The flow from this Feeder Canal provides operational water for the Champlain Canal. The Feeder Canal has two segments separated by the Old Canal and Bond Creek. Water diverted from the Hudson River at Glen Falls, NY flows via the first segment of Feeder Canal into Old Champlain Canal, which joins Bond Creek. The Bond Creek Dam diverts that flow into the second segment of Feeder Canal, which flows into the C8/C9 canal segment. The Feeder Canal is noted as a pathway for some waterborne invasive species to enter Lake Champlain, such as the spiny waterflea, though most species come from the Hudson River or Erie Canal system. Refer to **Figure 2** for a graphic identifying the lock and basin names throughout the Champlain Canal system. **Figure 7** includes a schematic diagram demonstrating the Champlain Canal infrastructure between Locks C7 and C9, including contributing waterways.

2.1.5 Dunham Basin

The pool between Locks C7 and C8 is referred to as the Dunham Basin, which is approximately 2.2 miles long and holds 27.6 million cubic feet of water. There is a diversion located at Argyle Street which allows flow from Dunham Basin into Bond Creek, where it then flows south to the Hudson River, bypassing Lock C7 (see **Figure 7**). This diversion is also used to drain the canal during non-navigational periods to accommodate access for maintenance and flood control. Plan and detail drawings of the Argyle Street diversion siphon spillway are provided in **Appendix B4**.

2.1.6 Smith Basin

The Bond Creek Dam keeps the flow in the Feeder Canal supplying water between Locks C8 and C9 (Smith Basin), approximately 6 miles apart. This section of the canal contains roughly 73.9 million cubic feet of water.

The contribution from the Feeder Canal varies seasonally. Based on field observations and desktop analysis of aerial imagery, the Old Champlain Canal does not flow north to reconnect to the Champlain Canal north of Lock C9; therefore, the old canal dead-ends at several locations along its northern reaches and does not provide a pathway for invasive species to move between the Hudson River Basin and the Lake Champlain Basin.

There is a spillway located south of Lock C9 on the east side of the canal that discharges to Wood Creek. Water from the canal is diverted through 4 siphons and an overflow weir to control the water level in Smith Basin. It is anecdotally understood to always have water spilling through the siphons. Water from the canal that is carried through the siphons and overflow weir discharges to Wood Creek and back into the Champlain Canal, north of Lock C9. It is reported that the average daily bypass flow over the Wood Creek spillway is approximately 50 MGD.

2.1.7 Summary of Watershed Data

Two major watersheds divide the study area between Locks C8 and C9. The Halfway Creek-Champlain Canal Watershed (which flows north to Lake Champlain) and the Snook Kill-Hudson River Watershed (which flows south to the Hudson River). Sub-watersheds supplying water to the Canal system were delineated using the USGS Stream Stats Tool (https://water.usgs.gov/osw/streamstats/). Physical and climatological characteristics for theses sub-watersheds are summarized in **Table 2** on the following page. These data are used to delineate which basins are contributing water to the canal system and to assist in the decisions for the alternatives analysis. **Figure 7** shows the other watersheds contributing flow to the Canal system in the study area.

Table 2. Sub-watershed Characteristics

Basin Characteristics			Halfway Creek-Lake Champlain Canal Watershed			Snook Kill-Hudson River Watershed	
	Parameter Description	**Unit**	Wood Creek	Big Creek	Unnamed Creek	Old Canal	Bond Creek
Physical Characteristics	Drainage Area	acres	8,902	21,371	926	1,202	8,867
		square miles	13.9	33.4	1.4	1.9	13.9
	Percentage of area covered by forest	percent	26.1	52.2	26.4	23.6	31.3
	Percentage of developed (urban) land from NLCD 2011 classes 21-24	percent	4.1	5.6	9.9	51.1	15.2
	Average percentage of impervious area determined from NLCD 2011 impervious dataset	percent	0.9	1.2	2.8	13.8	4.1
	Percentage of area of Hydrologic Soil Type A from SSURGO	percent	0.7	4.1	2.01	70.9	7.3
	Percentage of area of Hydrologic Soil Type B from SSURGO	percent	0.3	2.3	22.0	0	15.1
	Percentage of area of storage (lakes ponds reservoirs wetlands)	percent	1.8	1.4	0.1	0.3	6.5
Climatological Characteristics	Mean Annual Precipitation	inches	37.1	38.3	36.5	35.5	35.6
	Mean May Precipitation	inches	4.0	4.0	3.9	3.8	3.8
	Mean June Precipitation	inches	3.7	3.8	3.6	3.5	3.5
	Mean July Precipitation	inches	3.7	3.9	3.8	3.6	3.67
	Basin average mean precip. for June to August from PRISM 1971-2000	inches	11.6	11.9	11.4	10.9	10.9
	Mean annual runoff for the period of record in inches	inches	18.1	19.2	17.9	17.1	17.4
	50th percentile of seasonal maximum snow depth from Northeast Regional Climate Center atlas by Cember and Wilks, 1993	inches	19.4	19.6	19.5	19.3	19.4
	Maximum June Temperature, in degrees F	degrees F	77.9	77.4	78.1	78	77.8

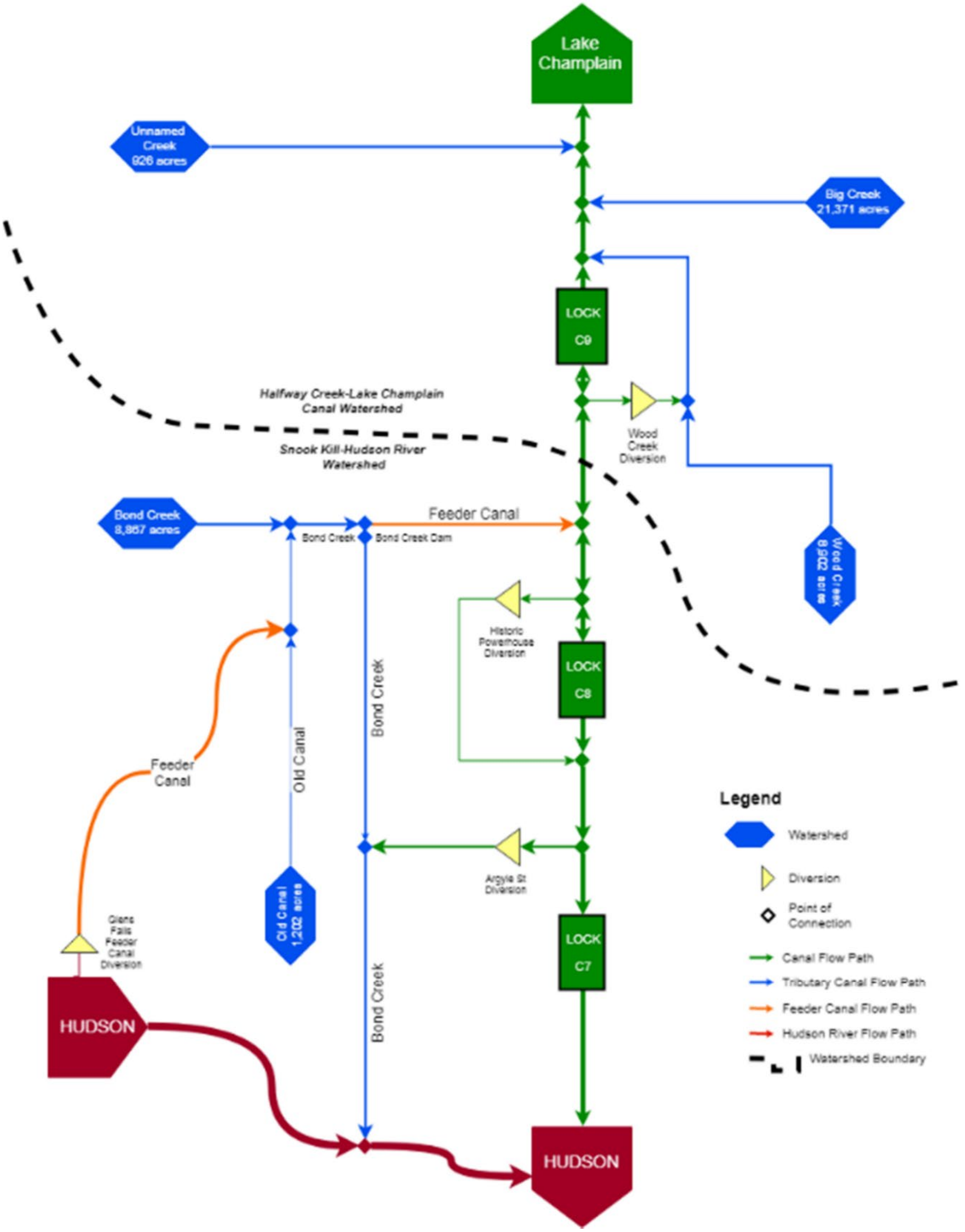


Figure 7. Champlain Canal Schematic (Locks C7-C9)

2.1.8 Canal Infrastructure Maintenance and Restoration

Per discussion with the NYSCC in January 2019, no major capital improvements or restoration activities are planned for the Champlain Canal within the study area. General routine maintenance is performed as needed to comply with the Canal Law, as discussed in Section 2.2 of this report.

2.2 Statute, Regulations & Governing Policies

The NYSCC operates under the authority of NYS Canal Law, NYS Public Authorities Law, and Canal Regulations (21 NYCRR 150-157) (New York State Canal Corp, n.d.). This legislation is referred to as the “Canal Law” and discusses the general powers and duties of the NYSCC regarding canal operation and maintenance, including contracting, acquisition or exchange of property, abandonment of canal lands, alteration of county or town roads, permitting and cargo reporting. Since the canal is on the historic register, any alterations to the canal itself may require coordination with the State Historic Preservation Office.

2.3 Utilities

Several utilities exist on site within the project study area, including; electrical power, potable water, natural gas, wastewater, and telecommunications. The utility locations and data associated with Locks C8 and C9 are shown on the drawings provided in **Appendix B5**. Access to existing utilities impact the feasibility of the proposed alternatives which is discussed later in this report.

2.4 Canal History and Operational Use

2.4.1 Construction & Historically Sensitive Areas

The first proposal to connect the tidal Hudson River with Lake Champlain by means of internal waterway improvements originated with the Northern Inland Lock Navigation Company in 1792. However, few improvements were constructed by the Company. Construction of the Champlain Canal was authorized by the NYS Legislature on April 15, 1817, and began later that same year. The Champlain Canal opened in its entirety in 1823, two years before the more storied Erie Canal. The canal was enlarged once in the 19th century, and rebuilt entirely in the 20th century, resulting in the waterway known today.

The current Champlain Canal was constructed as part of what was then called the New York State Barge Canal. Unlike the mule-drawn waterways of the 1800’s which featured man-made ditches and used natural water bodies for water supply only, the Barge Canal utilized natural lakes and rivers for the actual navigation channel as well. Today’s Champlain Canal (**Figure 8**) is comprised primarily of dug sections, while some remains of the former canals and feeders still exist along the modern system. The Glens Falls Feeder

Canal and the remains of its locks are easily viewable by taking a walk or bike ride on the old tow path. Refer to **Appendix B1** - Champlain Canal, Plans of Record (circa 1920) for representative construction drawings of Locks C8 and C9 which depict the layout and cross sections of these historic structures.

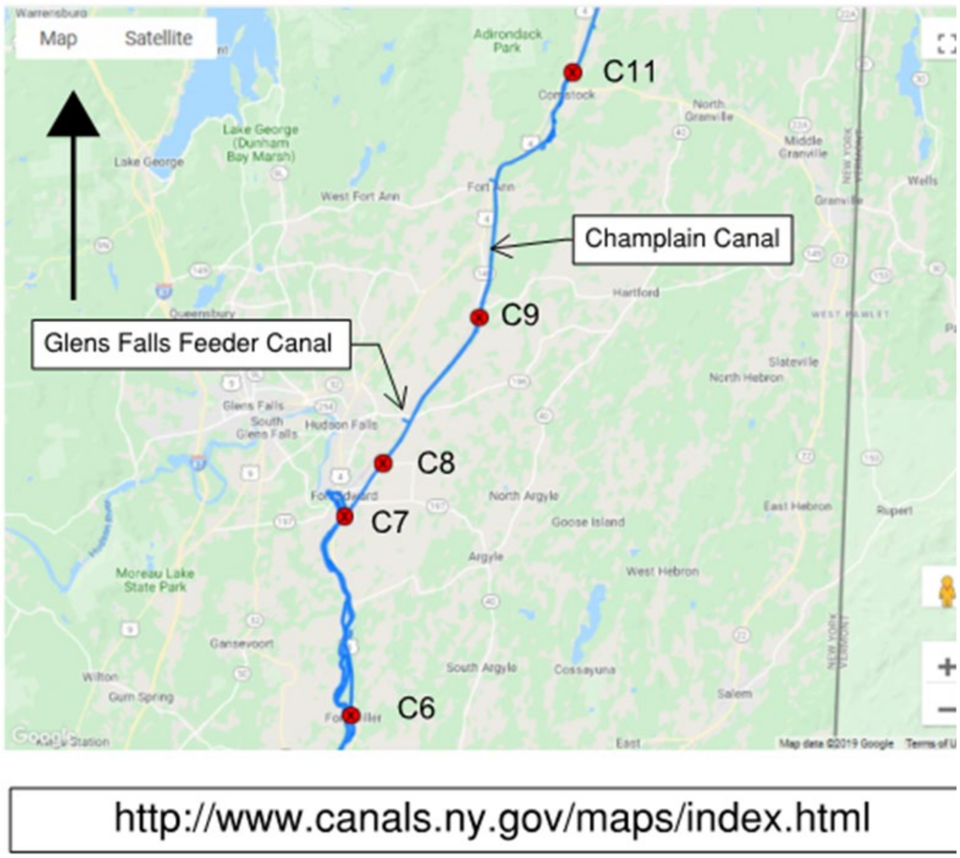


Figure 8. Champlain Canal System Location Map

The Champlain Canal is a lateral to the greater Erie Canal system. The construction of the Erie Canal began in 1817 and was opened in 1825. It includes approximately 338 miles of canalway (524 miles with all lateral connections included), which were enlarged multiple times to accommodate larger vessels over the following decades (New York State Canal Corporation, n.d.). The New York State Barge Canal is listed on the National Register of Historic Places. Refer to Appendix B1 - Champlain Canal, Plans of Record (circa 1920) for representative construction drawings of Locks C8 and C9 which depict the layout, profile, and cross sections of these historic structures, which remain largely unchanged today.

The Champlain Canal is owned and operated by the state of New York through the New York State Canal Corporation (NYSCC), a subsidiary of the New York Power Authority (NYPA). Any proposed plans for improvement or modification of the canal property must be submitted to NYSCC Department of Engineering for review.

As the canal system is on the National Register of Historic Places, any proposals for modifications of the facilities must comply with the environmental review process for historic resources. New York's State Historic Preservation Office (SHPO) is represented by the New York State Department of Parks, Recreation and Historic Preservation. The environmental review process is a planning process that helps protect New York's historic cultural resources from the potential impacts of projects that are funded, licensed, or approved by state or federal agencies. Under Section 106 of the National Historic Preservation Act and Section 14.09 of the New York State Historic Preservation Act, the SHPO's role in the review process is to ensure that effects or impacts on eligible or listed properties are considered and avoided or mitigated during the project planning process. Additional details regarding potential permitting requirements are discussed in the Alternatives Analysis section of this report.

2.4.2 Canal Use and Users

A summary of canal activities from 2009 through 2018 at Locks C8 and C9 was provided by the NYSCC. The navigational period runs from May through mid-October for recreational and commercial traffic. The canals may remain open through November to accommodate specific commercial vessels. Refer to **Table 3** below for a summary of lockage data.

Table 3. Lockage Data for C8 and C9

Lock	Average Lockages per Day	Average Lockages per Year	Commercial Traffic	Government Traffic	Recreational Traffic	Other / General Traffic
C8	7	1224	12%	5%	83%	0.1%
C9	7	1283	16%	5%	80%	0.1%

Note: these data are based on information received from the NYSCC, which includes lockage activity from 1 Jan. 2009 – 31 Dec. 2018 navigational periods.

Additional vessel traffic data, which breaks down the vessel traffic by size, was provided by the NYSCC during a technical planning meeting and is summarized in **Table 4** below.

Table 4. Vessel Traffic Data, Defined by Size

Vessel Size	Number of Boats	% of Traffic
<16'	46	2.4%
16-25'	132	7.0%
25-39'	920	48.8%
40-65'	725	38.5%
>65'	62	3.3%
Total	**1885**	

2.5 Stakeholders within the Lake Champlain Basin

A stakeholder meeting held in November 2008 was attended by the NYSCC, USFWS, NYSDEC, Lake Champlain Sea Grant, University of VT, USACE, NYS Federation of Lake Associations, Lake Champlain Research Institute, Adirondack Council, the Adirondack Park Invasive Plant Program, LCBP, NY Citizens Advisory Committee, the Lake George Association, The Nature Conservancy, VTANR, and VT United States Senators and local legislators. Additional stakeholders which may be engaged during future meetings include neighborhood associations, local governments, boating clubs, and others.

The primary suggested alternatives discussed at the 2008 meeting include "do nothing," biological, chemical, or behavioral barriers, hydrologic separation, and closing the canal. Other options mentioned include ultraviolet disinfection, boat washes, physical screening, heat-treating the water at the entrance to the Glens Falls Feeder Canal or the southern end of the Champlain Canal at Lock 8, educational outreach programs to recreational boaters through NYSDEC and others, and gaining funding for freight barges to have double-hulls and deep well pumps to change water in the ship ballasts.

The following ideas and concepts were noted during the November 2008 meeting:

- Do nothing: invasive species continue to persist within, threaten, and transit the Champlain canal-way, causing economic and ecological harm to the receiving waters.
- Biological barriers: may include the introduction of predator or grazing species to the canal to target invasive species; may be difficult to manage, added predators / grazers will not be effective against a range of organisms. There would be non-target species effects and could require a difficult regulatory process.
- Chemical barriers: such as a sodium hypochlorite solution followed by sodium bisulfate dechlorination; would have significant impacts on non-target species, although may be quite effective on the reduction of non-native species as well.
- Behavioral barriers: may include a bubble curtain to repulse fish and some plankton, the use of acoustics and a strobe which some fish avoid, and / or an electric barrier to repulse or kill fish. This will address a limited group of ANS and have few non-target species effects but do not work well against plants. Expensive; only works well for vertebrates and causes some human safety concerns.
- Hydrologic separation: physical barrier such as a closed canal lock that interrupts water connectivity. Feasible and addresses all organisms with minimal non-target species impacts. Installation costs would be high though maintenance costs are minimal. May consist of a boat lift to move vessels over the barrier with minimal threat of moving aquatic invasive species with the vessel during overland transport. Would cause traffic delays but also adds economic opportunities.
- Closing the canal: may cause loss of economic revenue, negative impacts on valued cultural heritage, and disconnection from the recreational corridor.

Under the current study effort, the Project Delivery Team (PDT) has held multiple meetings with USACE and other stakeholders to gain their input on preferred alternative measures and constraints, including a conference call on 10 October 2018, a site reconnaissance visit on 30 October 2018 and a second briefing conference held on 11 September 2019, which focused on the possible use of chemical treatment locks as a barrier alternative. Additional notes and outcomes from the site visit are included in Section 3.2.2 of this report. The specific ANS migration deterrent measures discussed during the October 2018 and September 2019 stakeholder meetings are described in Section 3.2.3 of this report.

2.6 Existing Aquatic Habitat & Environmental Conditions

2.6.1 Aquatic Habitat

The Champlain Canal is classified as a New York Class C stream (best usage is fishing) and is fed by several other streams including Halfway Creek, Big Creek, Wood Creek, and the Mettawee River. The canal is bordered in multiple areas by state regulated wetlands, particularly in the areas adjacent to Ft. Ann, the area north of State Route 196, and the northern end of the Canal, which also lies adjacent to floodplain forests in the lower end of the Poultney River. Other portions of the Canal are bordered by forested/shrub wetlands and smaller amounts of freshwater emergent wetlands. The area adjacent to the State Route 196 crossing is also adjacent to a raptor winter concentration area. The southern end of the Canal features largely agricultural surrounding land-use in addition to the aforementioned wetlands. The northern portion of the Canal is surrounded mostly by deciduous and coniferous forests. Areas of relatively increased urbanization include Ft. Ann, Whitehall, and Comstock.

Marsden and Ladago (2017) provide lists of fish, mollusk, crayfish, and plant species present in the Dunham basin as of 2010-2011. These include native species such as American eel (*Anguilla rostrada*), brassy minnow (*Hybognathus hankinsoni),* and several native species of pondweed (*Potamogeton sp.*). It should be noted that other portions of the canal contain the state-listed threatened species Eastern Sand Darter (*Ammocrypta pellucida*), as well as the Buffalo pebblesnail (*Gillia altilis*), a species of special concern. The canal also already harbors populations of several invasive species such as zebra mussels (*Dreissena polymorpha*) and Eurasian watermilfoil (*Myriophyllum spicatum*).

2.6.2 Environmental Conditions

The Invasive Species Inventory Report and Matrix (Appendix C) contains a detailed species list of both the aquatic species (plants, fish, invertebrates, etc.) that are native to Lake Champlain and the species that are non-native or are aquatic nuisance species (ANS).

As barrier alternatives to more effectively manage ANS are developed, it is important to account for all species present in Lake Champlain to increase effectiveness of ANS prevention while protecting native species. It is also integral to note the species that have yet to be found in Lake Champlain but pose a significant threat of intrusion into the Lake to optimize barrier method selection to prevent invasion. The species inventory (Appendix

C) has detailed life history strategies of ANS to better inform engineering alternatives for barriers. The document is broken down into native and invasive species with descriptions of the species for managers to make informed decisions on how to deal with various locomotion and dispersal methods.

The invasive species descriptions include the means of introduction into Lake Champlain, whether it is from active dispersal (fish swimming through a canal) or passive dispersal (ship ballast water). Each specie native range is identified as well as impacts of their introduction on native species. From the group of ANS identified, 3 areas of concern should be considered relative to overall life history and general dispersal strategy. More specifically, ANS in the Champlain Canal or that threaten to enter the Canal need to be addressed relative to:

1. Organisms that are freely swimming or moving through the canal waters or have life history stages that use freely swimming organisms as hosts,
2. Organisms who are dispersed by the currents or those that have a planktonic stage, and
3. Organisms that attach to boat/fishing equipment or can be transported in the bilge and ballast water of boats.

Several ANS are determined to be high priority for the implementation of a barrier system due to their negative impact to native species, efficiency of dispersal, and proximity of range relative to the Champlain Basin. In particular, thirteen (13) problematic species that are either present in Lake Champlain or have the potential to become established have been given larger attention.

Populations of the nonnative spiny waterflea (*Bythotrephes longimanus*) (1) and fishhook waterflea (*Cercopagis pengoi)* (2) have been discovered in Lake Champlain within the last decade, hypothesized to have been introduced via transport on watercraft and/or fishing gear. Also present is the nonindigenous fish species alewife (Alosa pseudoharengus) (3), an anadromous herring species that negatively impacts zooplankton populations, as well as the parasitic sea lamprey (Petromyzon marinus) (4), known to reduce populations of gamefish such as lake trout (*Salvelinus namaycush*; Fuller et al., 2019). While not known to be present in Lake Champlain, Eurasian ruffe (*Gymnocephalus cernuus*) (5) and round goby (*Neogobius melanostomus*) (6) have become established in the Great Lakes, putting regionally adjacent lakes such as Lake Champlain in danger of being invaded. Zebra mussels (*Dreissena polymorpha*, (7) which are present in Lake Champlain) and quagga mussels (*Dreissena bugensis*, (8) not yet in Lake Champlain) are prolific filter-feeders that deplete the water column of phytoplankton and foul water intake pipes. Though not of immediate top concern like the aforementioned species, it is worth mentioning that Asian carp and snakeheads are species of fish that are emerging as threats as well.

Nonindigenous aquatic plants present in Lake Champlain include Eurasian watermilfoil (*Myriophyllum spicatum*) (9) and water chestnut (*Trapa natans*) (10), two highly prolific species that can form dense populations, impeding boat navigation and outcompeting native species. Hydrilla (*Hydrilla verticillata*) (11), while not present in Lake Champlain, is a highly invasive plant species that often can grow to even denser populations than Eurasian watermilfoil. This plant can be very difficult to control once established and has been found in the Hudson River. Lastly, the wetland plants purple loosestrife (*Lythrum salicaria*) (12) and Japanese knotweed (*Fallopia japonica*) (13) are established on the shorelines of Lake Champlain, as well as in several other locations throughout the state of New York.

There are other aquatic nonnative and invasive species present or posing a threat to the basin, but not at the level of priority of those 13 noted above. These species are slower to disperse or more easily managed.

In addition to ANS, native species were also accounted for and included in the species inventory. Data gathered includes habitat and ecology, threatened and endangered status, food sources, life cycle, and demography. Each of these facets of native species are important to consider when determining the impact that the various barrier alternatives will have on native populations. Though the canals are manmade and native species would not otherwise be present without them, certain barrier options may have a negative impact on populations of sensitive species.

2.7 Future Without Project Conditions (FWOP)

Several ANS are determined to be high priority for the implementation of a barrier system due to their negative impact to native species, efficiency of dispersal, and proximity of range relative to the Champlain Basin. In particular, thirteen (13) problematic species that are either present in Lake Champlain or have the potential to become established have been given larger attention. For consideration of the FWOP (Future without project) or No-Action alternative, the species yet to invade Lake Champlain and their potential impacts to the Lake are clarified here.

Round Goby and Eurasian ruffe have become established in the Great Lakes putting regionally adjacent lakes, like Lake Champlain, vulnerable to introduction and habitation. These fish species displace native game fish species such as lake trout through competition for resources, predation on eggs and smaller age classes of gamefish, carry harmful fish diseases and pathogens such as viral hemorrhagic septicemia, and less predation pressure from native predators. Quagga mussels are also of particular concern; these bivalve mollusks are sessile as adults and prolific filter-feeders that deplete the water column of phytoplankton (thereby reducing plankton food resources for native species) and foul water intake pipes (increasing maintenance and operating costs at facilities where they settle). This is also evidenced by the current presence and impact of the similar species, the zebra mussel.

Plant species that would be of most concern for negatively impacting Lake Champlain if they were to infiltrate the waterbody is Hydrilla. This plant can be very difficult to control once established and has been found in the Hudson River. Hydrilla can grow faster than many native plants and since it can grow horizontally across the water surface once it reaches the surface, it can form mats that can shade out native plants. The dense mats of hydrilla can interfere with boating, fishing, and other recreational activities on the water.

Dense mats can also slow and change water flow in systems.

With consideration of a FWOP, presence and proliferation of these species over time would negatively impact the regional food web, cause displacement of native game fish and aquatic plants, alter the water quality of the lake (changing temperature and flow regime), impede recreational access in areas, and decrease the functionality of pipes. The potential benefits of a No Action alternative may be limited to having no temporary disturbance associated with the construction of any of the other alternatives and maintaining the current hydrology of the Canal.

Determining the costs associated with a FWOP/No Action alternative relative to projecting the extent of potential occupation by AIS would be highly speculative and likely not provide an accurate or meaningful value to evaluate as it would be highly variable and could cover a broad range. Following the format of USACE cost benefit assessments for planning and feasibility studies, this study uses an FWOP/No Action alternative cost of $0 in construction cost and does not include an assessment of future economic or ecosystem impacts of the no action alternative.

3 Plan Formulation and Evaluation

3.1 Planning Framework

The project team utilized a standard, three-step approach for developing alternatives: 1) gather general information about measures that may contribute to a solution to the problem, 2) narrow the list of measures through application of project-specific constraints, and 3) develop alternatives by combining measures that reduce or eliminate the cross-basin transfer of invasive species. The following sections describe these steps in more detail.

3.2 Management Measures

The project team reviewed historical studies and plans of record, engaged stakeholders as described in Section 2.5, and completed a site visit to identify measures for potential use in formulating alternative plans.

3.2.1 Historical Studies

The following historical studies were reviewed to develop an informed basis of opinion to identify previously considered solutions and new technologies to address the non-native and invasive species migration mitigation:

1. Feasibility of Champlain Canal Aquatic Nuisance Species Barrier Options (Malchoff, 2005)
2. Great Lakes Mitigation Report on Invasive Species (USACE, 2014)

The first study reviewed is a document specific to topics relating to the Champlain Canal which provides relevant background information and describes barrier measures already considered in past studies. The second study covers similar topics that have been evaluated under a much larger study conducted for the Chicago Area Waterway System to determine if any of the protective measures identified in that study could be adapted for use in the Champlain Canal study.

Feasibility of Champlain Canal Aquatic Nuisance Species Barrier Options

The Feasibility of Champlain Canal Aquatic Nuisance Species Barrier Options study (Malchoff, 2005) focused on limiting the transfer of sea lamprey, water chestnut, zebra mussel, and white perch from the Hudson Basin to the Lake Champlain Basin. Variable species removal efficiencies were allowed when alternatives were developed.

Six canal alternative plans were considered:

1) Do nothing;
2) Close the canal;

3) Physically and mechanically modify the canal to allow overland transfer of recreational vessels and use of a graving lock or seasonal lockage restrictions for commercial vessels;
4) Behavioral fish barriers (electrical, bubble, sound, strobe light – alone and in combination);
5) Chemical water quality barrier; and
6) Biological barrier.

The third alternative (physically and mechanically modify the canal) was evaluated to be the most effective at reducing the flow of canal-borne invasives. It was found to be the most effective protection against all taxa of aquatic nonnative and invasive species.

The 2005 Malchoff study identified the need for additional data collection and evaluation, including the following: Socio-economic surveys to better understand canal usage and importance, and engineering studies to predict the physical viability and costs associated with physical and mechanical barriers.

The study currently being conducted, builds on the ideas developed in the 2005 Malchoff study and provides further evaluation, siting, and cost considerations for the potential physical and mechanical modifications, plus investigates a new concept for chemical treatment systems.

Great Lakes and Mississippi River Interbasin Study

Great Lakes and Mississippi River Interbasin Study (GLMRIS) (USACE, 2014) focused on identifying a range of options to prevent the transfer of plant, animal or pathogen aquatic nuisance species between the Great Lakes and Mississippi River basins. A total of 13 species were targeted, including Bighead carp, a Diatom, Reed sweetgrass, and Grass kelp. Ninety-six technologies for minimizing and/or preventing the transfer of aquatic nuisance species were initially considered and narrowed down to a set appropriate for the Chicago Area Waterway System (CAWS) – the network of canals and channelized rivers connecting the two systems. Structural and non-structural controls were evaluated, including the following:

Structural

- New lock installation
- Lock pump-back
- Electric barriers
- ANS treatment plants
- Screened sluice, and

- Physical barriers

Non-Structural

- Net removal of fish
- Chemical water treatment
- Operational and boat cleaning controls, and
- Education programs

The PDT formulated six (6) alternatives for limiting the transfer of invasive species between the Lake Champlain and Hudson River basins. The types of alternatives considered focus on physical, mechanical and chemical methods with less consideration of water quality-based approaches due to the all taxa approach. The range of alternatives was made deliberately broad to capture the benefits and costs of substantial, and more limited, investment in solving the problems that cross-basin, invasive species transfers create. The six alternatives were initially reviewed with the project stakeholder working group to develop consensus from the group on the full array of alternatives to be considered. During subsequent stages of the project a facilitated stakeholder review and screening effort will be conducted to narrow the field to produce three (3) alternatives for further evaluation.

The GLMRIS study identified eight alternatives that utilized various combinations of the noted measures but did not identify a preferred alternative. Each alternative focused on different ANSs, as noted. The alternatives developed were the following:

Alternative 1: No Action – Current activities focused on limiting the cross-basin transfer of ANS to continue. Cost: $0.

Alternative 2: Nonstructural Technologies – Netting, chemical application, operation controls, boat cleaning before entry, educational programs. Species: Grass kelp, Reed sweetgrass, Tubenose goby. Cost: $68 million.

Alternative 3: Mid-System Control Technologies without a Buffer Zone – Nonstructural measures from Alternative 2, new lock installation flushing, Approach channels with electric barriers, ANS treatment plant, reservoirs, and conveyance tunnels to mitigate induced flooding. Species: Bighead carp, Silver carp, Bloody red shrimp, Grass kelp, Reed sweetgrass, Ruffe, Threespine stickleback, Tubenose goby. Cost: $15.5 billion.

Alternative 4: Control Technology Alternative with Buffer Zone: Nonstructural measures in Alternative 2, new lock installation with flushing, engineered channels, electric barriers, screened sluice gates, physical barriers. Species: Bighead carp, Silver carp, Bloody red shrimp, Grass kelp, Reed sweetgrass, Ruffe, Threespine stickleback, Tubenose goby. Cost: $7.8 billion.

Alternative 5: Lakefront Hydrologic Separation - Nonstructural measures in Alternative 2, physical barriers, treatment plants, reservoirs, and conveyance channels for induced flood mitigation. Species: Scud, Bighead carp, Silver carp, Bloody red shrimp, Diatoms, Fishhook water flea, Grass kelp, Red algae, Reed sweetgrass, Ruffe, threespine stickleback, tubenose goby, Viral hemorrhagic septicemia virus (VHSv). Cost: $18.4 billion.

Alternative 6: Mid-System Hydrologic Separation – Nonstructural measures in Alternative 2, physical barriers, treatment plants. Species: Scud, Bighead carp, Silver carp, Bloody red shrimp, Diatoms, Fishhook water flea, Grass kelp, Red algae, Reed sweetgrass, Ruffe, threespine stickleback, tubenose goby, VHSv. Cost: $15.5 billion.

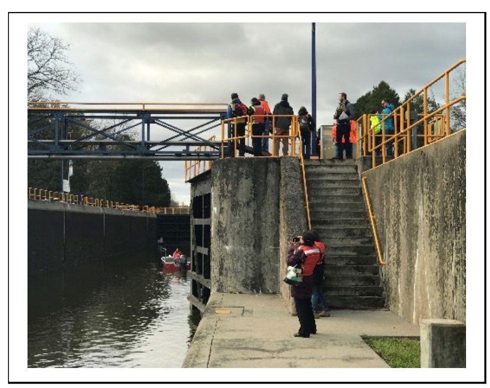
Alternative 7: Mid-System Separation Cal-Sag Open Control Technologies with a Buffer Zone – Alternative 2 nonstructural measures, physical barriers, new lock installation with flushing, electric barriers, engineered channels, electric barriers, treatment plants. Species: Bighead carp, Silver carp, Bloody red shrimp, a Diatom, Fishhook water flea, Grass kelp, Red algae, Reed sweetgrass, Ruffe, Threespine stickleback, tubenose goby. Cost: $15.1 billion.

Alternative 8: Mid-System Separation CSSC Open Control Technologies – Alternative 2 nonstructural measures, new lock installation and flushing, engineered channels, electric barriers, treatment plants. Species: Bighead carp, Silver carp, Bloody red shrimp, Diatoms, Fishhook water flea, Grass kelp, Red algae, Reed sweetgrass, Ruffe, Threespine stickleback, tubenose goby. Cost: $8.3 billion.

The magnitude of costs associated with the "Build Plan" alternatives in the GLMRIS ranged in value from $68 million up to $18.4 billion. While the scale of these potential projects far exceed the funding limits available under the Lake Champlain Watershed Environmental Assistance Program, the methodologies investigated by the study team provide insight on the technologies available to achieve the project goals of nonnative and invasive species migration deterrence. The PDT will draw upon these methodologies to determine if scalable adaptations of these methods can be tailored to fit the needs and resources of the Champlain Canal.

3.2.2 Project Site Visit

The PDT visited the site on October 30, 2018. The team reviewed the Lock C9 infrastructure, including the lock itself, the hydraulic system that opens and closes the lock, the power control room and office, and the nearby overflow weir that releases excess feedwater to Wood Creek. The canal separating Locks C8 and C9 was navigated in shifts, due to a boat size constraint. This allowed the channel boundaries and feedwater inflow point to be reviewed.



Lock C-9 in Operation

Several other locations and features pertinent to potential species transfer mitigation alternatives were inspected. These include the historical subsurface hydro-electric turbine chamber just north of Lock C8, and an overflow structure near Argyle Street between Lock C7 and C8. Both are structures that would play a role in any alternative that reduces feedwater overflow at Wood Creek and increases return flows of feedwater to the Hudson Basin. The take-off point where Hudson River water is diverted into the Glen Falls Feeder Canal was also reviewed. A complete set of field notes from the site visit are included in **Appendix D**.

3.2.3 Identified Measures

While the potential for AIS transfer between the Hudson River and Lake Champlain is limited to locations where water from either watershed is mixed, the primary focus of this study was at the summit canal between locks C-8 and C-9, as this would be the natural point of separation for the watersheds. Since limiting AIS transfer was the primary objective of this study, the possible solutions to meet the issue had to consider limiting the opportunity for AIS transfer to occur. Several measures are possible to satisfy the problems and needs of this objective; however, some of the measures are not practical or economical. The possible measures considered included: redirecting the Glens Falls Feeder Canal to the Hudson River Basin, add a back pump system to the existing lock system, utilizing an alternate make-up water source, creating a physical barrier between the two watersheds, installing a boat lift and cleaning station, utilizing wedge wire intake screens at locks, modifying the lock passage scheduling, installing a water filtration/ storage tank feed, repairing the lock seals, and creating a chlorination chamber. The Measures investigated are summarized below.

Measure 1 – Glen Falls Feeder Canal Redirection to Hudson Basin

Measure 2 – Back-Pump System

Measure 3 – Alternate Make-Up Water Source

Measure 4 – Physical Barrier (Berm Across Canal)

Measure 5 – Boat Lift and Cleaning Station

Measure 6 – Wedge Wire Intake Screen

Measure 7 – Modified Lock Passage Scheduling

Measure 8 – Water Filtration/Storage Tank Feed

Measure 9 – Repair Lock Seals, and

Measure 10 – Chlorination Treatment Chamber

The following paragraphs describe these ten measures in more detail.

Measure 1 – Glen Falls Feeder Canal Redirection to Hudson Basin

The feedwater and lock system were designed to provide a steady supply of Hudson River water to the system high point – the canal between Locks C8 and C9, and to modulate the available volume with a weir spillway that overflows to Wood Creek. Because Wood Creek is in the Lake Champlain drainage basin this feedwater overflow is the primary flow path of water from the Hudson River to the Lake Champlain basin. In terms of volume, the daily flow over the spillway is approximately 45-MGD, while the estimated flow through each lock C9 passage is 1.8-Million Gallons (MG). It would take on the order of 25 lock passages to equal the approximate daily flow over the spillway. The vessel traffic data indicates that the average daily number of lock passages is seven (7) per day, which is roughly equivalent to 28% of the daily water transfer from the Hudson to the Champlain basin.

Measure 1 would limit overflow to Wood Creek by raising the weir elevation and providing pathways for the excess feedwater to return to the Hudson River. A new overflow outlet, set at the original weir elevation, would be needed to route flow around Lock C8, discharging to the canal separating Locks C8 and C7. An existing outlet south of Argyle Street could possibly be modified to release that excess flow back to the Hudson River. The anticipated operating flow would be the same 45-MGD that currently enters Wood Creek, and the Lake Champlain Basin.

Implementing Measure 1 as part of species transfer mitigation alternative would reduce the flow of Hudson River water into the Lake Champlain Basin by approximately 72%, assuming seven (7) Hudson/Lake Champlain lockages a day during the navigation season.

Lock c-9 Spillway into Wood Creek

Argyle Street Drainage Structure

Measure 2 – Back-Pump System

Measure 2 uses volume replacement to replace lock water with water from the location the vessel is travelling to. For example, a scenario where a vessel travels from the Hudson River basin to the Lake Champlain basin through Lock C9 initially requires filling Lock C9 with Hudson River basin feedwater. Measure 2 would utilize a back-pump system to replace that make-up water with water located in the canal separating Lock C9 and C11 (see example pump in **Figure 9**). Given the current lock volume of 1.8 MG and the present fill time of approximately 15- minutes a pumping system would need to provide a flow of 120,000 GPM to equal the current flow rate into the lock. If the lock fill time could be approximately doubled to 30 minutes the pump size could be reduced to 60,000 GPM.

Some of the challenges with this system include defining a suitable point in the northern canal to draw this water from with confidence it was predominantly Lake Champlain basin water, power requirements (initial infrastructure and operation and maintenance) and having the appropriate permits to construct this system.

Figure 9. Displacement Pump

Measure 3 – Alternate Make-Up Water Source

The alternate water supply system would utilize the natural stream flows available in the surrounding drainage basins to either replace or augment the flows contributed by the Glens Falls Feeder. If enough natural flow contribution can be obtained, then the Glens Falls Feeder could be shut down or reduced in flow.

There are two local basins which could provide makeup water for the C8/C9 canal, including the Bond Creek and the Wood Creek basins. Each of these basins have drainage areas exceeding 8,000 acres which could be substantial contributions of flow for make-up water. This approach would reduce the systems dependency on Hudson River water and reduce aquatic nonnative and invasive species originating from the Hudson River from entering the lock system.

Measure 4 – Physical Barrier

This measure includes installing a physical barrier, such as an earthen berm or concrete cut-off wall, across the C8/C9 basin, preventing boat traffic from travelling from one basin to the other. The obvious advantage to implementing this measure is that it reduces cross-basin transfer of waterborne species with the highest degree of certainty. The downside to this measure is elimination of all benefits derived from cross-basin commercial vessel traffic.

Measure 5 – Boat Lift and Cleaning Station

Study Team in boat on Summit Canal

A boat lift and cleaning station would reduce the risk of ANS transferring between basins by reducing the species that may be present in vessel ballast water, as well as those that physically adhere to the hull of the vessels. This measure would involve the installation of a permanent boat lifting device with rollers to carry the boat above the water to be cleaned, and then pass over the closed lock gates. This measure would utilize a mechanical lift system rather than the water lift system currently utilized by the locks, which would therefore eliminate the need for 1.8-million gallons of water transfer during a typical lock C9 passage.

This option is likely expensive and maintenance-intensive, yet effective against the transfer of invasive species between drainages. However, not all boats may be lifted and cleaned due to their size (i.e., commercial cargo vessels). The number of instances where a lockage would occur will be reduced when using the boat lift for cleaning and transferring smaller recreational vessels over Lock C9 completely. Plan views and a photo of the proposed boat lift and cleaning system are shown in the **Figure 10, Figure 11 and Figure 12** below.

Figure 10 below depicts the plan view of Lock C9 as the base drawing with an overlay (shown in red) of the proposed crane pathway system that would be required to vertically lift small to medium sized boats, then transfer them horizontally across the upper lock gate completing the transfer of the vessels from the lower to upper canals or vice versa.

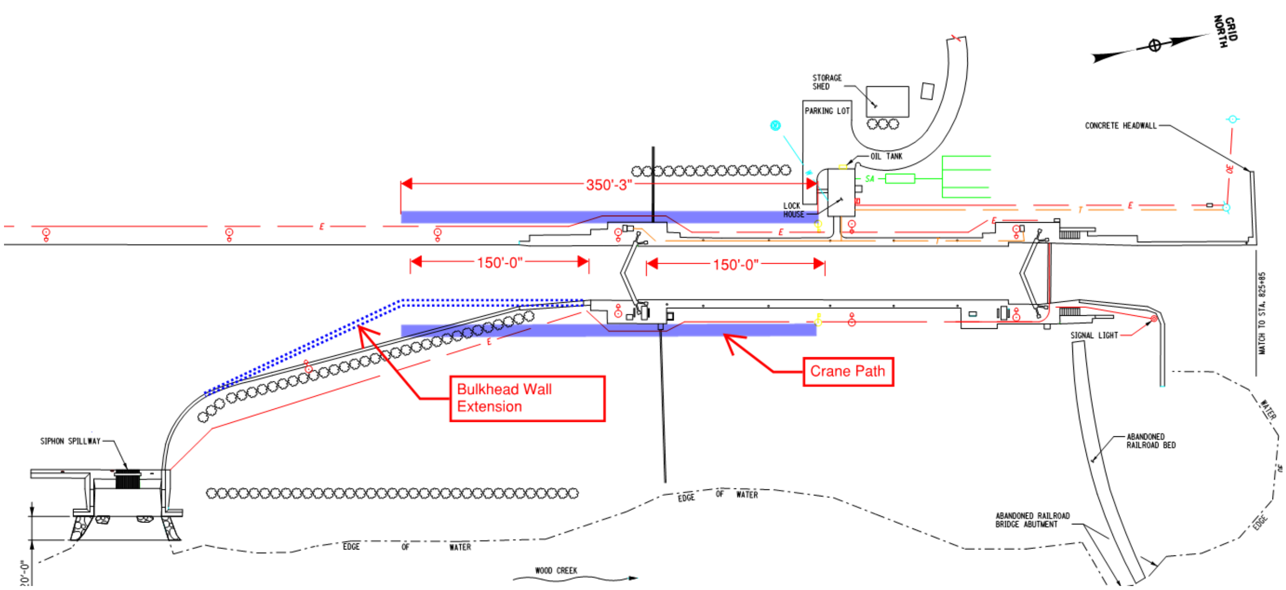


Figure 10. Marine Lift System – Concept Plan

Base image from As Built Drawing sheet no. 111, Plan and Elevation of Lock No. 9, Contract No. 25

Figure 11 below presents a photograph of a marine boat lift system for lifting, then transporting small to medium sized vessels. This mechanical boat lift system could be integrated into the Lock C9 system to replace the hydraulic lift system currently in place. The dry lift system avoids the transfer of 1.8-million gallons of water during lock passage.

Figure 11. Example Marine Boat Lift System for Small/Medium Vessels

Figure 12 below shows a concept plan layout of a boat cleaning station that would be used in conjunction with the mechanical boat lift system. Boats would be lifted from the water, transported to a cleaning station where hot water with high pressure would be applied to the boats to cleanse and kill organisms on the outside surfaces, bilge and engine water would be emptied and flushed with hot water, collected and disposed of before the boat would be allowed to be placed back into the water at the next water level.

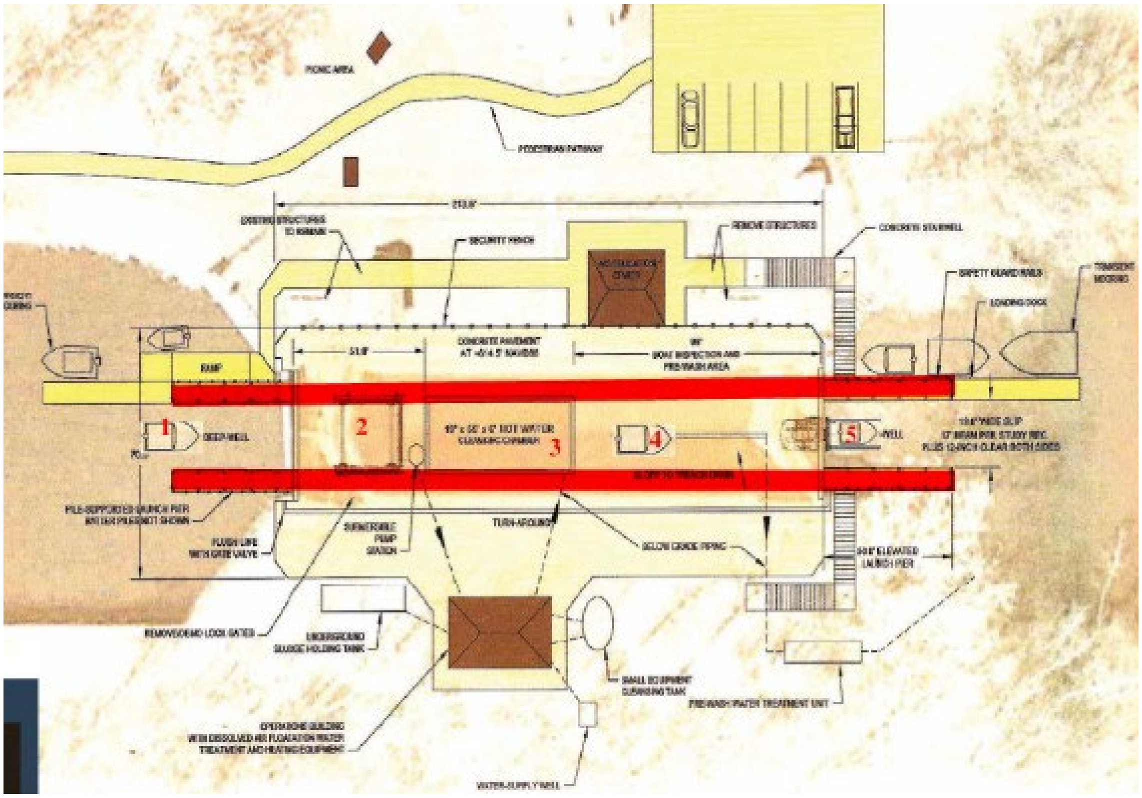


Figure 12. Boat Cleaning Station for Small Vessels – Conceptual Plan

The cantilever arm system shown in **Figure 13** below could be mounted on a berm, separating the up and downstream portions of the canal. The arm could rotate the boat 180 degrees around the berm.

Figure 13: Small Vessel Boat Lift via Cantilever Arm

https://www.ascom-italy.it/products/1/3.html

The Measure 5 Boat Lift and Cleaning Station would have significant operational costs, require additional work effort by the lock operations staff for each passage and take on the liability of physically handling privately owned vessels.

Measure 6 – Wedge Wire Intake Screen

Wedge wire intake screens may be installed to filter water transferred from the C8/C9 basin into Lock C9 or C8. The screens would be installed upstream of the existing intake conduits on the floor of the canalway and require installation of an extension of the existing box culverts which are used to fill the lock. The screens would need to be installed in a manner that does not impede or inhibit vessel traffic safety. One of the great benefits of this treatment system is that the locks would still be operated via a gravity fed water transport system which would maintain the current operating systems in the current conditions and the physical modifications to the system would not be visible from the surface.

Figure 14 below provides a plan view schematic drawing of how the Wedge Wire Screen system would be adapted to the existing lock water intake system. The wedge wire screens filter ANS such as fish, plants, eggs, and insects. They may not address the concerns of all microscopic invasive species. They require little maintenance other than routine cleaning and biofouling removal. Lock filling times may be increased by the wedge wire screens and would need to be studied further to determine acceptable limits as related to screen filtration capacity.

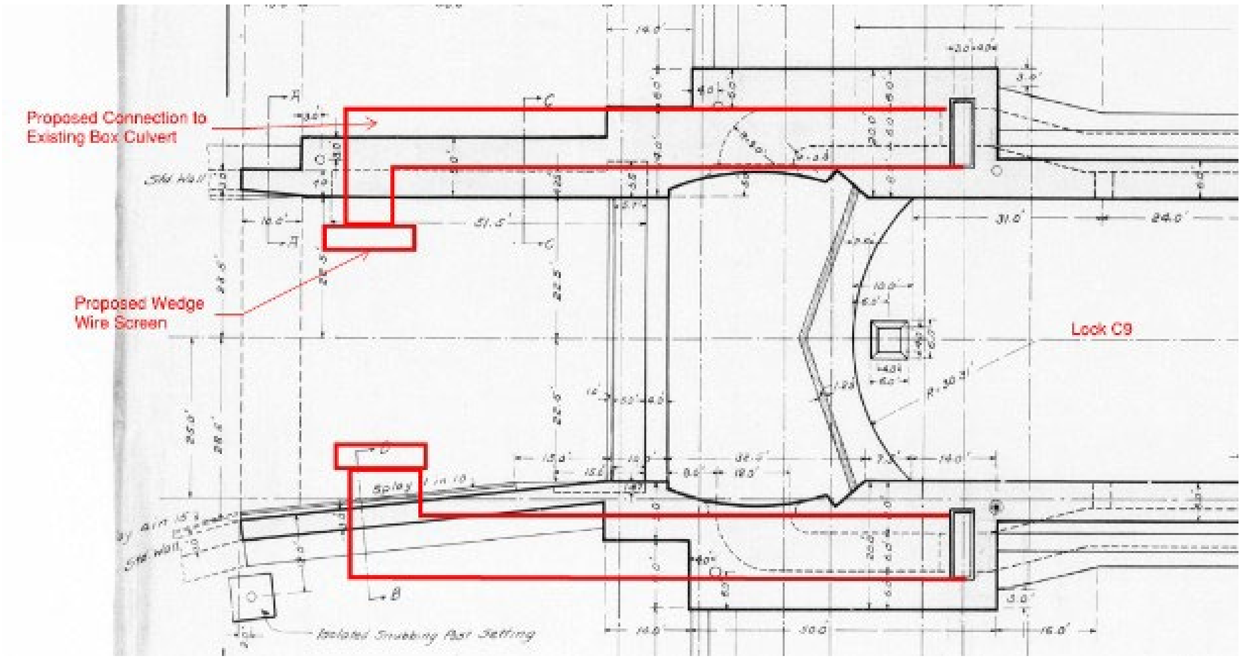


Figure 14. Lock Feedwater with Wedge Wire Screen – Conceptual Plan

Figure 15 below provides a three-dimensional visual depiction of a Wedge Wire intake screen apparatus. Further hydraulic studies need to be conducted to properly determine the number and size of the intake screens needed to provide adequate water flow rate to ensure lockage times are not adversely extended. Further physical evaluations need to be conducted to determine the positioning of the intake screens within the canal and the piping/conduit configurations to ensure the modified intake structures do not impede safe navigation and the new system is accessible for future maintenance and operation procedures.

Figure 15. Screen Intake Structure

https://www.hendrickcorp.com/screen/markets/water-intake-water-treatment/

Measure 7 – Modified Lock Passage Scheduling

Reducing the number of lockages at Locks C8 and C9 would reduce the volume of water exchanged between the Hudson River and Lake Champlain, potentially reducing the risk of cross-basin transfer of invasive species. A simple approach includes modifying scheduled lockages. For example, Lock C9 may only open for recreational boat traffic during certain times throughout a given day during the navigational period - such as 9am, 12pm, and 3pm - instead of opening and closing the lock for a single boat when they arrive at the lock. Another approach would be to open the lock when there are enough vessels in queue to completely fill it. This measure may reduce but will not eliminate the transfer of waters from the two basins. This measure requires no additional maintenance or cost. The challenge would be potential inconvenience it would introduce to boaters on the canal – a problem that would likely diminish over time as they became more familiar with the lockage schedule.

One of the challenges of extending the duration of waiting for a lock passage may be how to occupy the time of the boaters during this layover period. On site improvements such as rest facilities, educational programs, hiking programs or picnic facilities may be low-cost options to address this possible inconvenience and turn the waiting period into desirable activity for recreational boaters.

Measure 8 – Water Filtration/Storage Tank Feed

Example Water Storage Tank
https://www.globaltechdb.com/portfolios/city-of-cooper-city-two-million-gallon-ground-storage-tank/

Measure 8 is a volume replacement operation that would utilize filtration and a storage tank system to provide water for use during lockage process at Lock C9. Removal of ANS may be achieved by using a wedge wire intake screen, as described above, and a sand filtration system. These processes would address most plants, and fish, and some although not all microscopic invasive species.

For north-bound vessels, a pumping system is required to discharge Lock C9 water into the C8/C9. Once drained the lock is filled with filtered tank water via gravity flow. The north-bound vessel then enters the lock, causing additional basin C8/C9 water to enter Lock C9. Additional filtered water is then charged from the tank to dilute this addition. An overflow pipe installed in Lock C9 will return flow to the C8/C9 basin until the desired dilution volume is met.

For south-bound vessels, the lock is drained north into the C9/C11 canal and will be filled with water from the C8/C9 canal. The tank would contain enough water necessary to completely fill Lock C9, which is approximately 1.8 MG. Assuming a tank height of 40 feet, the footprint of the tank would be a minimum of 7,850 square feet, having a diameter of 100 feet.

Operational costs will be significant to maintain the filtration system, the pump station to transfer the water to the storage tank, and pumps to drain Lock C9. A proposed location for a Lock C9 system and tank is provided below in **Figure 16**.

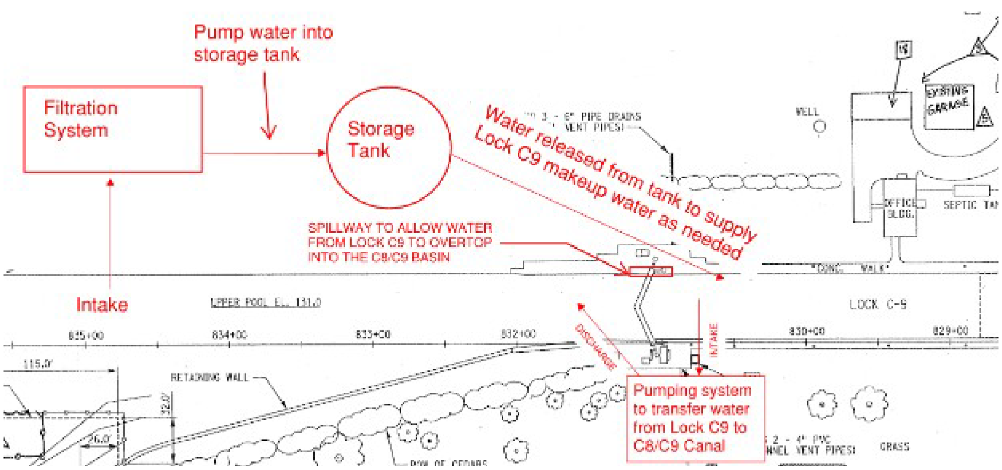


Figure 16. Filtration/Storage System.

Image from As Built Drawing no. GP-1, General Plan and Work List – Rehabilitation of Lock C-9

Measure 9 – Repair Lock Seals

Measure 9 includes retrofitting the lock gate vertical boundaries to reduce seepage. Substantial seepage, on the order of 50 gpm, was observed flowing from the C8/C9 basin into Lock C9 between the gate and canal wall boundary and between the two gate panels (**Figure 17**). Microscopic to small ANS can be transported by this seepage. Reducing or eliminating it will reduce cross-basin transfer of ANS.

Figure 17. Seepage Flow Observed During Site Visit

Measure 10 – Chlorination Treatment Chamber

Measure 10 includes creating an isolated treatment chamber along the canal pathway where a vessel can be moored for a short period of time (approximately 30 to 60 minutes) while chemical additives are mixed into the chamber volume to first chlorinate the water, then allow the chlorine contact time to react with and exterminate the ANS, then add a dechlorination chemical to the chamber, allow the water to neutralize, then open the gates to allow the decontaminated vessel to pass. The location of such a treatment chamber would need to be positioned along the C8/C9 canal someplace between north of the feeder canal and the northern Lock C9. The size of the treatment chamber would need to match the size of the existing lock chambers to allow for all passage of all size vessels currently using the canal. The basic chamber size would be approximately 45-ft wide, 330-ft long and at least 12-ft deep to match the depth of the main canal.

During the study two options for the location of the treatment chamber were investigated. The first option would involve retrofitting the existing Lock C9 to be utilized as the treatment chamber, refer to **Figure 18** below. This option would require constructing chemical storage and chemical mixing buildings at Lock C9 and installing distribution pipes with mixing jet nozzles to the existing lock. Due to several difficulties implementing this option, this version of Lock C9 modification is not proposed as a feasible option. The description of this option is included in this report to acknowledge its consideration.

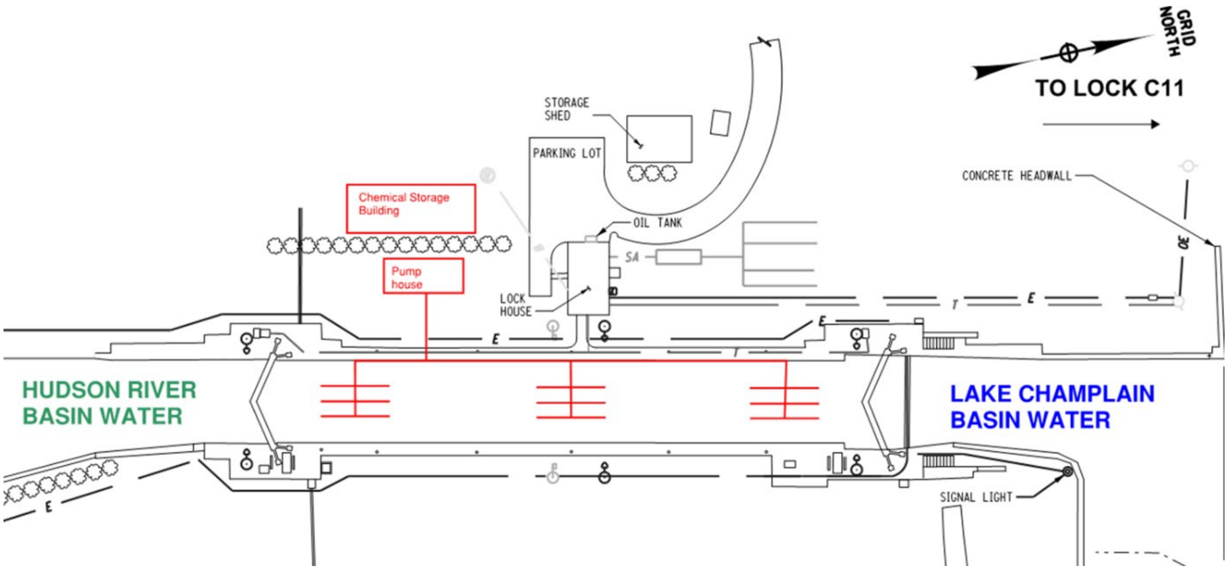


Figure 18. Chlorination Treatment Chamber Layout at Lock C9.

The second option was to construct a new at grade treatment lock north of the feeder canal along a narrower portion of the canal. **Figure 19** below depicts a plan view of a potential treatment lock location situated just south of the Route 196 Bridge. This option would require constructing chemical storage and chemical mixing building at a new site and constructing a new concrete lock treatment chamber. The new treatment lock would be constructed with the necessary distribution pipes and mixing jet nozzles. This second option also requires developing a new lock site along the canal-way for vessels to pass through and filling a portion of the canal to provide closure across the width of the canal.

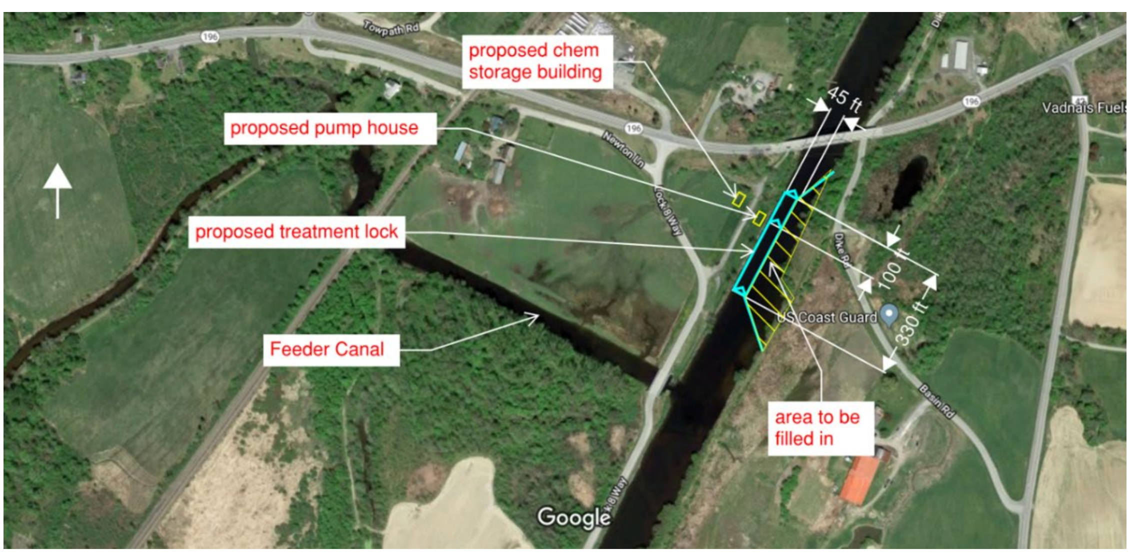


Figure 19. New Chlorination Treatment Chamber at Route 196.

This concept consists of building a new lock chamber, matching the length and width of the existing lock chambers, 330’x45’ (these are the same dimensions as Locks C8 and C9 which accommodate barge traffic). The new lock will be located just south of NYS Route 196, and just north of the feeder canal entry point. This would be an at grade lock, providing no lift or drop for the vessels. The canal area adjacent to the treatment lock will be filled in to avoid the bypass of canal water around the lock.

To create a scalable solution for different size vessels an intermediate set of lock gates will be installed to create three possible configurations: 1) 110-ft, 2) 220-ft or 3) 330-ft. The size of the treatment chamber can be set to accommodate different size vessels.

Operation Procedure: The boat will enter the lock; two sets of gates will close depending on the boat size. Sodium hypochlorite will be mixed within the treatment lock. A pump will agitate the water within the lock to ensure adequate mixing (via paddles, air bubbles, other). The vessel will wait the minimum contact time (likely 30-60 min.) for the chlorine to be effective against ANS. After that time, sodium bisulfite will be added as a dechlorinator which is effective immediately. The gates will then open, and the vessel can leave the treatment lock. Fish kill-off management or sensory deterrents would need to be addressed. Possible deterrent techniques could include bubble screens or electric fields across the canal way, upstream and downstream of the treatment lock.

The proposed lock, chemical storage building, and pumps would likely fit within the NYSCC’s right-of-way; no additional easements would be required. The chemical storage building and pump housing dimensions would be determined under a future, more detailed study. An initial assessment of the building size based on similar function buildings would be roughly 3,300-SF (33’x100’). Vehicular access to the new lock site can be achieved through the existing road Lock 8 Way. Electricity is available at this location.

During the September 2019 stakeholder’s conference, the two options for the location of the treatment chamber were discussed and the table below summarizes the findings of those discussions (refer to **Table 5**).

Table 5. Chlorination Alternatives

Topic	Option 1 – Retrofit Existing Lock C9	Option 2 – Construct New Treatment Lock
Power & Chemical Usage	**Significant** - Would generally require more power and chemicals overall due to greater volume of lock exchange than a "new" treatment lock (16' lift +12' draft = 28' depth vs. 12' depth) only one configuration possible. Treatment Vol. = 330'x45'x28' = 415,800-CF / **3.1-Mil Gal**.	**Moderate** - Would need to supply power and chemicals for pumps to mix or stir treatment chamber at approximately 12' depth. Installation of interior chamber gate provides three volume options. Treatment Vol. = 330'x45'x12' = 178,200-CF / **1.30-Mil Gal**. or 220'x45'x12'= **0.88-Mil-gal.** or 110'x45'x12'= **0.44-Mil-Gal**
Boat Access	**Minimal** – Chemical distribution piping mounted on walls of Lock C9 may interfere with boats when moored. Allows passage of all vessels. Boat travel time generally unaffected.	**Minimal/Moderate** - Will require additional half hour to pass through new lock, adding to travel time. Allows passage of all vessels. Requires additional time to travel through new treatment lock.
Construction Requirement	**Moderate**- requires construction of chemical storage building, pump house and chemical distribution piping to be attached to lock walls and bottom of channel.	**Significant**- requires construction of new concrete lock, filling in canal channel, gates, chemical storage building, pump house, employee building, and other site plan improvements.
Site Plan		
Staffing requirements	**Minimal** - Additional chemical storage and handling training may be required.	**Significant** - New employee(s) need to be stationed at new lock location; additional chemical storage and handling training may be required.

Table 5. Chlorination Alternatives		
Topic	**Option 1 – Retrofit Existing Lock C9**	**Option 2 – Construct New Treatment Lock**
Historic Sensitivity	**Moderate** - Would cause impact to existing Lock C9, including installation of storage building, mixing system, pump house, and piping.	**Minimal** - Would only impact the canal channel between Feeder Canal and NYS Route 196. No direct impacts to existing locks C8 and C9.
Location	**Minimal** - Likely would fit within NYSCC ROW at the Lock C9 site, no additional land acquisition.	**Minimal** - Likely would fit within NYSCC ROW, no additional land acquisition. Would need to verify that the structure does not generate erosive velocities at the NYS Route 196 bridge abutments.
Cost	**Moderate/Significant** – 1) Initial construction costs include construction of a new pump house, chemical storage building and site modifications. 2) Need to train new staff member(s) for chemical storage and handling. 3) Long term costs of chemical and power would be greater than Option 2.	**Significant** – 1) Overall initial construction cost likely higher than retrofit, due to construction of a new lock, backfilling the canal, new access road and other site improvements. 2) May need to add staff to operate the new lock unless staff from C8 and C9 could cover new Lock. 3) Long term costs of chemical and power would be lower due to smaller volumes of treated water needed for lock passage.

Collectively the PDT considered the factors listed in the above table and concluded that only Option 2, construction of a new treatment lock would be acceptable. All further discussions of this Measure 10 – Chlorination Treatment Chamber, will be based on the construction of a new chamber. It is also recognized that the location of the treatment lock could vary from this initial siting, so long as the alternative locations are located further north than the currently selected site and south of Lock C9.

It is important to note that the sodium hypochlorite additive to lock water used to control ANS would have varying effects on different species. Contact times differ across taxa; further, data available for effective concentrations and contact times is limited. Most fish species, Daphnia spp. and harmful bacteria would be controlled with 5-15 mg/L at 30 minutes of contact time, with significantly high mortality rates (**Table 6**). Selected references include Brooks & Seegert (1977), Seegert & Brooks (1978), Larson *et al.*(1978), Sheedy *et al* (1991), Martin *et al* (1993), Wetsers (2001), Clearwater,*et al.* (2008), Barbour *et al* (2013), and Medina, Kilgore, & Hoover, (2018).

Table 6. Chlorine Effectiveness Against Certain ANS		
Species Treated by Proposed Sodium Hypochlorite of 5-15mg/L @ 30min (based on selected references)	**Species Treated by Proposed Sodium Hypochlorite of 5-15mg/L @ 60min (based on selected references)**	**ANS needing greater dosage concentration or contact time in order to be treated (based on selected references)**
Bighead and silver carp	Bighead and silver carp	*Corbicula fluminea*, Asian Clam
Daphnia mendotae, Daphnia spp.	*Daphnia mendotae, Daphnia spp.*	Gammarid amphipods
Rainbow trout	Rainbow trout	*Dressinia polymorpha*, Zebra mussel
Yellow perch	Yellow perch	Various protozoa
Bluegill sunfish	Bluegill sunfish	
Emerald shiner	Emerald shiner	
Spottail shiner	Spottail shiner	
Channel catfish	Channel catfish	
Smelt	Smelt	
Alewife	Alewife	
Most fish species	Most fish species	
Most harmful bacteria	Most harmful bacteria	

Some priority species however, such as the Asian clam (*Corbicula fluminea)* and the Zebra mussel (*Dressinia polymorpha*), among others, require extremely high concentrations and/or contact times to achieve acceptable effectiveness for ANS control. Finally, management of remains from any organisms, specifically fish, killed by chlorination control measures would need to be considered.

Table 7 provides a summary of various invasive species' susceptibility to chlorine and an estimate of their mortality rates.

Table 7. Invasive Species Susceptibility to Sodium Hypochlorite Solutions				
Species	**Concentration**	**Time**	**Mortality Rate**	**Reference(s)**
Corbicula fluminea (Asian clam)	2%	5 min	93%	Barbour*et al.* (2013).
Harmful bacteria (general)	5–10 mg/L	1-24 hrs	100%	Clearwater,et al. (2008).
Most fish (general)	5 mg/L	<1 hr	most	Clearwater,et al. (2008). Medina, Kilgore, & Hoover, (2018) Brooks & Seegert (1977) Seegert & Brooks (1978) Larson et al (1978) Westers (2001)
Bighead and Silver carp	10 mg/l	10-20 min	100%	Medina, Kilgore, & Hoover, (2018) Larson et al. (1978)
Daphnia mendotae	1.6 mg/L	Not reported	60-75%	Raikow, D. F., Landrum, P. F., & Reid, D. F. (2007). Larson et al. (1978)
Dreissena polymorpha	2.5 mg/L	264 hr	100%	Martin, M. D., Mackie, G. L., & Baker, M. A. (1993).
Protozoa	31.6 mg/L	7 days	Not reported	Sheedy, et al. (1991).
Scud	12.5%	15 min	100%	Medina, Kilgore, & Hoover, (2018)

3.3 Arrays of Alternatives

The PDT developed six (6) alternatives using combinations of the measures that can reduce or eliminate cross-basin transfer of ANS. The team deliberately made the range of alternatives broad so that the costs and benefits of large and smaller investments could be considered. **Table 8** was assembled and applied to allow the team to consider alternative development using the full suite of measures. **Appendix E** contains concept layouts for each alternative.

Table 8. Summary of Alternative Components

Control Measure	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
1) Reverse Flow C9 → C8, Raise Weir	X	X	X	X	X	X
2) Back Pump		X	X			
3) Alternate Makeup Water			X			
4) Physical Barrier (Berm / Block Flow)		X				
5) Boat Lift and Cleaning Station		X		X	X	
6) Wedge Wire Intake Screen			X	X		
7) Modified Lock Passage Scheduling and Operations	X		X			
8) Water Filtration / Storage Tank Feed			X			
9) Repair Lock Seals	X	X	X	X	X	X
10) Chlorination Treatment Chamber						X

The elements of the six Alternative plans are summarized below, and the following sections discuss the alternatives in more detail:

Alternative 1 – Summary of Measures, Minimal Feature Plan:

- Measure 1) Reverse Flow C9 -> C8, Raise Weir,
- Measure 7) Modified Lock Passage Scheduling, & Operations and
- Measure 9) Repair Lock Seals

Alternative 2 – Summary of Measures, Physical Barrier Plan:

- Measure 1) Reverse Flow C9 -> C8, Raise Weir,
- Measure 2) Back Pump,
- Measure 4) Physical Barrier (Berm / Block Flow),
- Measure 5) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals

Alternative 3 – Summary of Measures, Water Filtration Plan:

- Measure 1) Reverse Flow C9 -> C8, Raise Weir,
- Measure 2) Back Pump,
- Measure 3) Alternate Makeup Water,
- Measure 6) Wedge Wire Intake Screens,
- Measure 7) Modified Lock Passage Scheduling & Operations,
- Measure 8) Water Filtration / Storage Tank Feed, and
- Measure 9) Repair Lock Seals

Alternative 4 – Summary of Measures Small Boat Lift Plan:

- Measure 1) Reverse Flow C9 -> C8, Raise Weir
- Measure 5) (Small) Boat Lift and Cleaning Station,
- Measure 6) Wedge Wire Intake Screens, and
- Measure 9) Repair Lock Seals

Alternative 5 – Summary of Measures, Large Boat Lift Plan:

- Measure 1) Reverse Flow C9 -> C8, Raise Weir,
- Measure 5) (Large) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals

Alternative 6 – Summary of Measures, Chemical Treatment Plan:

- Measure 1) Reverse Flow C9 -> C8, Raise Weir,
- Measure 9) Fix Lock Seals, and
- Measure 10) Chlorination Treatment Chamber

3.3.1 Alternative 1 – Raise Weir, Modified Schedule, Repair Seals

Alternative 1 – Raise Weir includes;

Measure 1) Reverse Flow C9 → C8, Raise Weir,

Measure 7) Modified Lock Passage Scheduling, & Operations and

Measure 9) Repair Lock Seals.

This alternative includes raising the spillway weir at the Wood Creek diversion to meet existing surrounding grade. This will mitigate the discharge of water from the Hudson River basin into the Lake Champlain basin. Infrastructure improvements to re-route this water back to the Hudson River are also required to transport the excess flows to Lock C8 or lower (Hudson River basin) and expand the Argyle Street outlet structure to accommodate this additional flow. This alternative would reduce discharge of Hudson River basin water into the Lake Champlain basin by approximately 45 MGD. Boat traffic would not be impeded, and locks would remain operational. Additionally, the lock gates at C9 would be repaired to reduce leakage when closed. As observed during the site visit in October 2018, the leaks may contribute up to 50 gpm (72,000-GPD) of water between basins.

The other component of this measure includes modifying the lockage operation and schedule. Each lockage exchange is between approximately 1.1-1.8 million gallons of water. Currently, the average number of lockages a day is 7; by scheduling lockages at set times throughout the day, this could be reduced to 3 or 4. The locks could also operate once there are enough vessels in queue to fill the lock.

Summary of Alternative 1 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Expand / improve Argyle Street outlet structure
- Repair seals on lock gates
- Institute the scheduled passages for vessels via public notice, signage, pamphlets, etc.
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Would be constructed within NYSCC right-of-way; no additional land or easement acquisition required
- Effectiveness: Alternative 1 greatly reduces the flow between watersheds; however, transfer is possible during lockages, particularly for free swimming organisms (whether AIS specifically or AIS that attaches to or parasitize native species)

3.3.2 Alternative 2 – Raise Weir & Physical Barrier

Alternative 2 – Raise Weir & Physical Barrier includes;

Measure 1) Reverse Flow C9 → C8, Raise Weir,

Measure 2) Back Pump,

Measure 4) Physical Barrier (Berm / Block Flow), Measure 5) Boat Lift and Cleaning Station, and

Measure 9) Repair Lock Seals.

This alternative includes raising the Wood Creek spillway and providing return flow pathways to the Hudson River as discussed in Alternative 1, with an additional permanent berm located upstream of the spillway. The berm and raised weir elevation would generally prevent water from the Hudson River basin entering the Lake Champlain basin. Small recreational vessels would be loaded onto a trailer via a boat ramp, cleaned, and then brought down a ramp on the opposite side. Large recreational vessels would be less than 100 feetlong would be lifted by a boat lift , cleaned at the berm, and then deposited on the other side of the berm. Large commercial boat traffic across Lock C9 would be discontinued. The lifted boats would utilize a cleaning station which would capture and store washwaters in a storage tank on land adjacent to the canal. The stored washwater would routinely be transported offsite for proper treatment and disposal. The makeup water used to fill Lock C9 would be provided through the natural flows from the Lake Champlain Basin, if further studies indicate, a back-pump system which pulls water from the Lake Champlain basin, north of C9, into a storage tank, which is then released into the lock during an exchange could be necessary.

Summary of Alternative 2 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Expand / improve Argyle Street outlet structure
- Repair seals on lock gates
- Construct berm south of Wood Creek Spillway, north of Lock C8
- Install small boat lift, cleaning station and washwater storage tank
- Install pump north of Lock C9, storage tank, and piping to discharge back into Lock C9 (If necessary)
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Would be constructed within NYSCC right-of-way; no additional land or easement acquisition required.
- Effectiveness: Alternative 2 greatly reduces Hudson River water from entering the Lake Champlain Basin. The proposed boat lift, and boat ramp would address the transfer of smaller AIS in bilges and attached to hulls, however these measures would not accommodate large commercial vessels.
- Commercial traffic loading landing sites have been identified south of Lock 8 and north of Lock 9 that could be modified to allow for cargo to be transported by land around the physical berm.

3.3.3 Alternative 3 – Raise Weir, Back Pump & Alternate Makeup Water

Alternative 3 – Raise Weir, Back Pump & Alternate Makeup Water includes;

Measure 1) Reverse Flow C9 → C8, Raise Weir,

Measure 2) Back Pump,

Measure 3) Alternate Makeup Water,

Measure 6) Wedge Wire Intake Screens,

Measure 7) Modified Lock Passage Scheduling & Operations,

Measure 8) Water Filtration / Storage Tank Feed, and

Measure 9) Repair Lock Seals,

This alternative includes the Alternative 1 measures plus a back-pump system to replace Lock C9 process water. The water for the volume replacement may be provided from 2 sources: (1) pumping water out of the C8/C9 basin, through a sand and gravel filtration system and into a storage tank (most abundant / consistent source- see Measure 2), or (2) pumping water from the Lake Champlain side of the canal, through the filtration system and into a storage tank (alternate makeup water source – see Measure 3). To store enough water for a complete lock displacement, the tank may be approximately 40-ft. high and 100-ft. in diameter. The stability of the Champlain canal's contributing drainage area north of Lock C9 is unknown and likely variable (i.e., the unnamed creek and Big Creek as shown in **Figure 7**); therefore, the primary water source would be from the Hudson River basin. Both intakes would have a wedge wire screen to prevent some larger ANS from entering the filtration system.

The system would be operated as follows:

1) North-bound vessels:
    a) Lock C9 is empty.
    b) Close northern Lock C9 gates.
    c) Fill Lock C9 from filtered water in the storage tank.
    d) Open southern Lock C9 gates.
    e) Boat enters the filled Lock C9.
    f) Close southern Lock C9 gates. Water from the upper canal will mix into the Lock C9, including Hudson River Basin water.
    g) Continue to over-fill Lock C9 at the southern end with treated water. Overflow will be discharged back into the C8/C9 canal way via an overflow pipe,

circumventing the southern Lock C9 gates and flushing out the Hudson River Basin water from the Lock.

h) Lockage operations proceed. Treated water within Lock C9 will be discharged north to the Lake Champlain Basin.

i) Once the lock has emptied, the northern gates have opened, and the boat can complete its passage into the C9/C11 canal.

2) South-bound vessels:

a) Lock C9 is at low water elevation. The southern gates are closed.

b) Boat enters Lock C9.

c) Close northern Lock C9 gates.

d) Fill Lock C9 from filtered water in the storage tank.

e) Open southern Lock C9 gates.

f) Allow boat to exit Lock C9 into the Hudson River Basin.

g) Close southern Lock C9 gates. Water from the C8/C9 canal will mix into the Lock C9, including Hudson River Basin water.

h) Continue to over-fill Lock C9 at the southern end with treated water. Overflow will be discharged back into the C8/C9 canal way via an overflow pipe, circumventing the southern Lock C9 gates and flushing out the Hudson River Basin water from the Lock.

i) The treated water now stored in Lock C9 can be held until the next boat passage determines the required lockage operations.

This alternative would generally reduce Hudson River basin water from entering the Lake Champlain basin; however, some mixing of Hudson water will occur during lockages. Boat traffic would not be impeded, and locks would remain operational. Lock gate seals would also be repaired.

Summary of Alternative 3 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin
- Expand / improve Argyle Street outlet structure
- Install pump to retrieve Lock C9 water and discharge into basin C8/C9 for north-bound vessels
- Install pump station to retrieve water from between Locks C8 and C9 with wedge wire screened intake and discharge to storage tank
- Install pump station to retrieve water from Champlain basin side of the canal and discharge to storage tank
- Construct sand and gravel filtration system

- Construct spillway to allow overflow from Lock C9 into C8/C9 canal
- Install storage tank to receive treated Hudson River basin water and / or Lake Champlain basin water, with gravity drain to Lock C9
- Repair seals on lock gates
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Would be constructed within NYSCC right-of-way; no additional land or easement acquisition required
- Effectiveness: Alternative 3 builds on preventative measures of AIS by more effectively addressing planktonic organisms being passed through the waterway, however it still remains possible for free swimming organisms to move through during lockages and for organisms to be conveyed in boat bilge or on hulls

3.3.4 Alternative 4 – Raise Weir, Intake Screens, Small Boat Lift

Alternative 4 – Raise Weir, Intake Screens, Small Boat Lift, includes;

Measure 1) Reverse Flow C9 → C8, Raise Weir,

Measure 5) Boat Lift and Cleaning Station,

Measure 6) Wedge Wire Intake Screens, and

Measure 9) Repair Lock Seals

This alternative includes raising the Wood Creek spillway and providing return flow pathways to the Hudson River as discussed in Alternative 1, with a small recreational boat lift, for vessels up to 30 feet in length, and cleaning station. Boat traffic across Lock C9 would be allowed for all boats, including cargo and freight vessels. Small boats would cross the closed northern Lock C9 gates via a cantilever arm boat lift. The lifted boats would utilize a cleaning station which would capture and store washwaters in a storage tank on land adjacent to the canal. The stored washwater would routinely be transported offsite for proper treatment and disposal.

Summary of Alternative 4 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Expand / improve Argyle Street outlet structure
- Repair seals on lock gates
- Install small boat lift, cleaning station and washwater storage tank

- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Would be constructed within NYSCC right-of-way; no additional land or easement acquisition required.
- Effectiveness: Alternative 4 would generally reduce Hudson River Basin water from entering the Lake Champlain Basin, except during commercial vessel and large marine vessel lockage. This alternative also addresses AIS in bilge and on boat hull.

3.3.5 Alternative 5 – Raise Weir, Marine Boat Lift

Alternative 5 – Raise Weir, Marine Boat Lift, includes;

Measure 1) Reverse Flow C9 → C8, Raise Weir,

Measure 5) Boat Lift and Cleaning Station, and

Measure 9) Repair Lock Seals,

This includes the Alternative 1 measures, as well as a marine boat lift at Lock C9. This boat lift would transport vessels up to 100 feet in length. It would include a tow path and lift system to transport boats across the southern gate of Lock C9 and lower it either up or downstream of the lock. The bulkhead on the eastern side of the canal may need to be extended to configure the tow path system. The boat lift would include a cleaning station and associated storage tank for washwaters adjacent to the lock. Cargo vessels could be accommodated on a limited basis; however, no water treatment method is provided. This alternative does not impede boat traffic throughout the canal and generally reduces the exchange of water from the Hudson River basin to the Lake Champlain basin for boats less than 100 feet long. Lock gate seals would also be repaired. Alternative 5 would allow less water to pass between the Hudson and Champlain watersheds than Alternative 4 as the locks would only be opened for commercial traffic.

Summary of Alternative 5 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Expand / improve Argyle Street outlet structure
- Install large boat lift, cleaning station and washwater storage tank
- Repair seals on lock gates
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Would be constructed within NYSCC right-of-way; no additional land or easement

acquisition required

- Effectiveness: Alternative 5 would generally reduce Hudson River Basin water from entering the Lake Champlain basin and would not impede vessel traffic. This addresses transfer of AIS in water and conveyed via boat (hull or bilge water).

3.3.6 Alternative 6 – Raise Weir, Chlorination Treatment Chamber

Alternative 6 – Raise Weir, Chlorination Treatment Chamber, includes;

Measure 1) Reverse Flow C9 → C8, Raise Weir,

Measure 9) Fix Lock Seals, and

Measure 10) Chlorination Treatment Chamber

This includes the Alternative 1 measures, as well as a constructing an in-canal treatment lock with chemical storage and mixing facilities on the shoreline.

This alternative does not impede boat traffic throughout the canal and generally prevents the exchange of water from the Hudson River basin to the Lake Champlain basin. Lock gate seals would also be repaired.

Summary of Alternative 6 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Expand / improve Argyle Street outlet structure
- Install treatment lock and chemical storage tank at new site along canalway north of Feeder Canal
- Repair seals on lock gates
- The northern portion of the channel from the chlorination treatment lock to Lock C9 would not be emptied of water during the winter months
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- State Pollutant Discharge Elimination System (SPDES) Permit for dechlorinated water discharges
- Would be constructed within NYSCC right-of-way; no additional land or easement acquisition required
- Effectiveness: Alternative 6 would generally prevent Hudson River Basin water from entering the Lake Champlain basin and would not impede vessel traffic.

This addresses transfer of AIS in water and conveyed via boat (on hull or in bilge). Further, it addressed AIS that may potentially be conveyed during lockages. However, the diversity of AIS species of concern have a wide range of required contact times and concentrations for chlorination treatment to be fully effective for all species of AIS.

4 Plan Evaluation, Comparison, and Selection

The benefits and costs of the alternative plans, including the no-action or FWOP alternative, were evaluated and the plans were compared to each other on the basis of their respective benefits and costs. USACE's Engineering Research and Development Center (ERDC) performed Multi-Criteria Decision Analysis (MCDA) and Cost-Effectiveness and Incremental Cost Analysis (CEICA) to evaluate and compare the plans. Three of the six action alternatives were screened out using MCDA. CEICA identified two of the remaining three action alternatives as cost-effective: Alternative 2 and Alternative 4. Although Alternative 4 has lower incremental costs than Alternative 2, the benefits of Alternative 2 are much higher than the benefits of Alternative 4. Alternative 2 meets the planning objectives and is the recommended plan.

The follow sections describe plan evaluation, comparison, and selection in more detail. Appendices H and I document the MCDA and CEICA process and results, respectively. Appendix G contains the basis of the conceptual cost estimates prepared for alternatives 2, 4, and 5.

4.1 Stakeholder Engagement and Technical Coordination

4.1.1 Initial Stakeholder Meeting

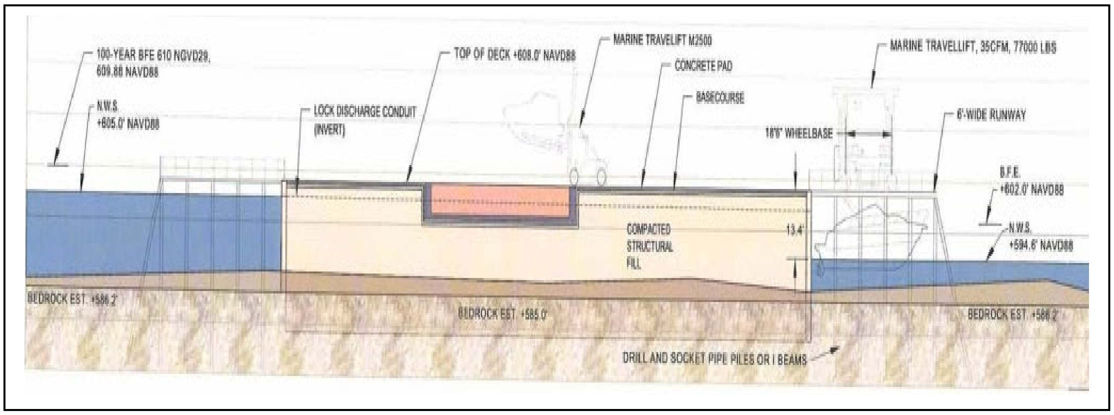
Stakeholders were first introduced to the MCDA concept in 2018.

The PDT held a stakeholder meeting on June 2-5, 2020, to review the existing conditions and proposed alternatives with the stakeholders. During the 2020 meeting, stakeholder breakout groups brainstormed criteria and presented their ideas to a larger group, where an overall criteria list for the MCDA was compiled. At this time, a subset of stakeholders also volunteered to participate in the Technical Committee which would evaluate the alternatives. Finally, the stakeholders voted to pursue consideration for three of the six alternatives presented at the 2020 meeting: alternatives 2, 4, and 5. The designs for these alternatives would be refined and the Technical Committee would use the MCDA framework to evaluate their merit according to stakeholder values.

The three alternatives that stakeholders voted to continue considering included:

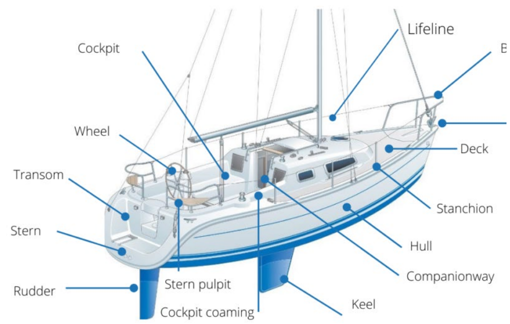
Alternative 2 –Physical Barrier includes;

- Measure 1) Reverse Flow C9 → C8, Raise Weir,
- Measure 4) Physical Barrier (Berm / Block Flow),
- Measure 5) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals.



Alternative 4 – Raise Weir, Intake Screens, Small Boat Lift, includes;

- Measure 1) Reverse Flow C9 → C8, Raise Weir,
- Measure 5) Boat Lift and Cleaning Station,
- Measure 6) Wedge Wire Intake Screens, and
- Measure 9) Repair Lock Seals



Anatomy of a Simple Sailboat

Alternative 5 – Raise Weir, Marine Boat Lift;

- Measure 1) Reverse Flow C9 → C8, Raise Weir,
- Measure 5) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals,

Of the three preferred alternatives, **Alternative 2** appeared to be the favored alternative for the majority of the stakeholders and the local sponsor, LCBP, because the implementation of the physical berm across the channel would provide the greatest deterrence to interbasin species migration. However, this alternative also presents the greatest obstacle to commercial shipping in the canal. Under Alternative 2, commercial shipping related goods would need to be off-loaded to trucks, travel via roadway past the berm, then reloaded to barges/boats on the other side of the berm to continue traveling via the waterway. The berm alternative would also hamper the canal operations and maintenance vessels from having unimpeded access to the waterway.

Alternatives 4 and 5 maintain the lock for the scheduled use by commercial vessels only (during low-risk times/season). All other small vessels are to be transported over the lock using a boat lift(s). Due to the vessel size restriction on Alternative 4, more lock passages would be required to allow for vessels over 30 ft to traverse the lock. Alternative 5's vessel size restriction (100 feet) allows for more recreational vessels to be lifted, without the normal water transfer during lock operation.

4.1.2 Follow up Stakeholder Meeting and Clarifications

On October 2, 2020, a follow up meeting was held with USACE, ERDC, LCBP, NYSCC, NYPA, and A/E representatives. The purpose of the discussions was to provide answers for questions raised as a result of the Stakeholders Alternatives Screening meeting held in June 2020. The PDT reached out to NYSCC to clarify several topics. Two topics regarding canal system operation that pertain to plan formulation and evaluation and may warrant further investigation are highlighted below.

Topic 1 - Hydro Power: The first topic raised by NYPA was whether the NYSCC had an obligation to release flow from the canal to the north towards Lake Champlain to provide feeder water to a hydro-electric plant located somewhere north of Lock C9. The design team needs clarification on this issue as one of the measures included in all six alternatives is to reverse the feeder water overflow from Lock C9 to Lock C8 where the waters would reenter the Hudson River rather than the Lake Champlain basin.

NYSCC indicated that the agreements to provide flow to the Hydro Power plant has a long history, being as old as the canal system itself. Upon reviewing the original 1927 easement with this powerplant, NYSCC determined that they have the right to withdraw whatever water necessary to conduct vessel operations, and that the hydropower plant is entitled to natural base flows from Wood Creek and other local natural streams. This easement also indicated that the plant is not entitled to any additional flow from the Hudson River canal feeder stream.

The clarification provided by this easement review resolves the concerns over the redirection of the feeder canal water from the northern flow path towards Lake Champlain to the southern flow path back to the Hudson River.

Topic 2 – Commercial Vessel Passage: The second topic raised was how to address commercial use of the canal. The unobstructed passage of large vessels is only possible without the cross-canal barrier berm that is the key element of Alternative 2. The berm is considered to be an essential alternative measure by the stakeholder group.

The stakeholder group considers the berm more effective at preventing the transfer of AIS between the Hudson and Champlain basins, than the other two alternatives (4 and 5). Therefore, many stakeholders would prefer to include a trucking bypass as part of the Alternative 2 to keep commercial use of the canal to the extent possible. Currently, commercial vessels can move unimpeded through the canal. Alternative 2 would essentially eliminate all large commercial vessel traffic in the summit canal, thereby separating Lake Champlain from the Hudson River.

The PDT has identified a potential location for an off-loading facility, but additional work is required to determine the feasibility of this location, in order to make an informed decision on the preferred alternative. The PDT inquired with NYSCC on the different types of vessels contributing to traffic in the canal. There are three different classes of vessels that can use the canal. The first class is recreational vessels which are the most prevalent class recorded using the canal. While this class is fairly broad it is expected that the largest recreational vessel would be approximately 45-ft. The second class is industrial class vessels which are the largest class that operate in the canal. It was noted that the Coast Guard has larger vessels in this category ranging from 60-ft to 90-ft and 75 to 100 tons of displacement. Dredging barges are also included in this class and typically range from about 45-ft to 60-ft. The third class of vessel that travel through the canal are commercial vessels, typically aggregate barges. The PDT was advised that the major company that utilized the canal for this use has not been shipping through the canal in the last 2 years, but that when they were utilizing the canal there were approximately 3 barges per day that travelled through the canal. Refer to **Figure 20** for an example of the typical aggregate barge traveling through a canal (not an actual photo of the Champlain Canal).

Figure 20. Example Aggregate Barge in canal.

The additional discussions held regarding the conflict between the Alternative 2 berm and commercial vessel passage have helped to better define the issues to be addressed. Additional studies would be required to resolve the unanswered questions regarding a landside bypass for large commercial vessels or their goods being transported. Alternative 2 as currently configured does not provide a solution to this aspect of commercial vessel passage.

4.2 Updated Selected Alternatives

4.2.1 Alternative 2 – Physical Barrier

Alternative 2 –Physical Barrier includes;

- Measure 1) Reverse Flow C9 → C8, Raise Weir
- Measure 2) Back Pump (currently eliminated from Alternative 2),
- Measure 4) Physical Barrier (Berm / Block Flow),
- Measure 5) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals.

Alternative 2 includes providing return flow pathways to the Hudson River as discussed in Alternative 1, with an additional permanent berm located upstream of the Glens Falls Feeder Canal. The berm would generally prevent water from the Hudson River basin entering the Lake Champlain basin. This berm will be placed north of the feeder canal and just south of the Route 196 bridge. Large commercial vessel traffic across Lock C8 would still be allowed, however barges would need to transfer their cargo via alternate land-based routes as barges cannot be lifted over the berm. A transfer station would need to be constructed capable of allowing barges to be loaded and offloaded. There is an existing barge loading facility to the south of Lock C8 (see **Figure 21**) which may be suitable. This facility is currently owned by the US EPA who is in the process of transferring the ownership, possibly to the NYSCC.

Figure 21. Barge Loading Facility south of Lock C8.

The berm constructed across the summit canal would contain one boat ramp for the transfer of smaller vessels and a second boat slip equipped with a large boat lift to transfer vessels across the top of the berm. Small recreational boats up to 30 feet in length will be transported via a boat trailer and pickup truck over the berm utilizing boat ramps. There will be multiple trailers to accommodate boats of different lengths. A second boat slip will be equipped to lift 30-ft to 100-ft long vessels over the berm. Shown in **Figure 22** below is a general layout plan of the berm, ramp and slip configuration.

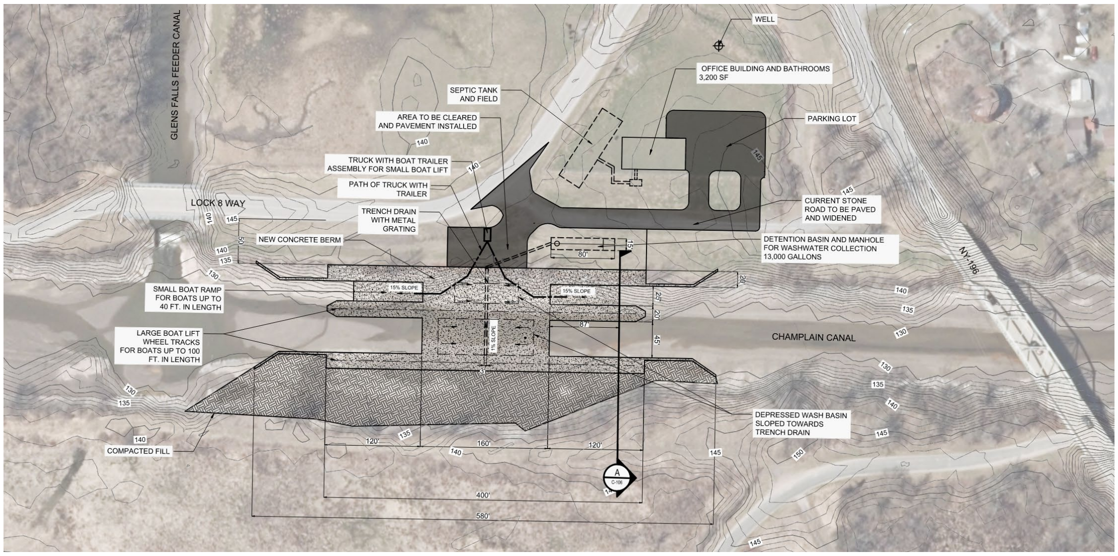


Figure 22. Alternative 2 General Layout Plan.

There will be cleaning stations located on the top of the berm. Washwater will be captured and stored in a large underground storage tank on land adjacent to the canal. The stored washwater would routinely be pumped and transported offsite for proper treatment and disposal.

Summary of Alternative 2 Implementation:

- Construct a conduit to re-route excess feed water back into the Hudson River Basin at Lock C8
- Repair seals on lock gates
- Construct berm between feeder canal and Route 196
- Install large boat lift, cleaning stations, trench drain and washwater storage tank
- Construct office building, parking lot, bathrooms, other desired amenities, and access road
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Construction or acquisition of a new barge loading facility will be required to allow commercial shipping to continue (this feature is not accounted for in the construction cost estimate for Alternative 2)
- **Effectiveness:** Alternative 2 greatly reduces Hudson River water from entering the Lake Champlain Basin; small boat access ramp and large boat lift equipped with boat wash stations addresses transfer of smaller AIS in bilges and attached to hulls, acquisition or construction of barge loading facility addresses commercial vessels.

4.2.2 Alternative 4 – Raise Weir, Intake Screens, Small Boat Lifts

Alternative 4 – Raise Weir, Intake Screens, Small Boat Lifts, includes;

- Measure 1) Reverse Flow C9 → C8, Raise Weir
- Measure 5) Boat Lifts and Cleaning Station,
- Measure 6) Wedge Wire Intake Screens, and
- Measure 9) Repair Lock Seals

Alternative 4 includes raising the Wood Creek spillway and providing return flow pathways to the Hudson River as discussed in Alternative 1, combined with two (2) small boat lifts, and a connecting roadway with a boat cleaning station. Small boats, 30-ft long or less, will cross Lock C9 by the two proposed cantilever arm type boat lifts, which are located on the north and south ends of the lock. On the north side, boats up to 30-ft long and 30 tons in weight, would enter the small harbor and be lifted up and placed on a boat trailer. A pickup truck would then tow the boat on the trailer to the new wash platform, where the exterior of the boat will be washed, and bilge water drained. All washwater and bilge water would be collected and stored in an underground tank, near the new platform. To transport the boats from the north and south ends of the lock a new access road would need to be constructed. The stored washwater would routinely be transported offsite for proper treatment and disposal. Refer to **Figure 23** for a General Layout Plan of Alternative 4. Note, a sub-alternative to this option may include using a boat ramp instead of a boat lift on the north side of the lock, where the water surface elevation differential is relatively small.

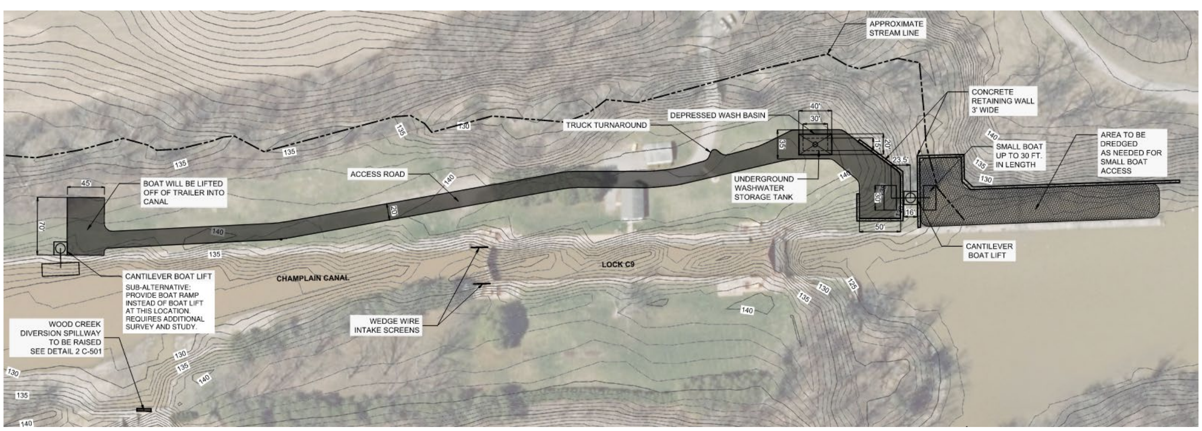


Figure 23. Alternative 4 General Layout Plan.

Larger boats including commercial cargo and freight vessels (greater than 30-ft long) will continue to pass through the lock system as they currently do. To reduce the potential for AIS exchange during the lock passage, the intake ports to the lock manifolds will be equipped with wedge wire screens.

Summary of Alternative 4 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Repair seals on lock gates
- Install 2 small boat lifts, cleaning station and washwater storage tank
- Procure and install boat wash mechanical systems; water heater, pressure tanks, hoses, spray guns
- Construct new access road to allow passage between north and south boat lifts
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- The new facilities would be constructed within NYSCC right-of-way; no additional land or easement acquisition required.
- **Effectiveness:** Alternative 4 would moderately reduce Hudson River Basin water from entering the Lake Champlain Basin. This alternative also addresses AIS on the boat hull and in bilge. These goals are achieved by allowing vessels smaller than 30-ft long to bypass Lock C9 via the lift system and overland route. Vessels greater than 30-ft would still require passage through Lock C9.

4.2.3 Alternative 5 – Raise Weir, Marine Boat Lift

Alternative 5 – Raise Weir, Marine Boat Lift, includes;

- Measure 1) Reverse Flow C9 → C8, Raise Weir,
- Measure 5) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals,

Alternative 5 includes the Alternative 1 measures, as well as a marine boat lift at Lock C9. The large boat lift would transport vessels up to 100 feet in length. It would include a tow path and lift system to transport boats across the southern gate of Lock C9 and lower it either up or downstream of the lock. The bulkhead on the eastern side of the canal will need to be extended to configure the tow path system.

To accomplish the boat cleaning process, the vessel is lifted and a washwater containment barge will be placed beneath the raised vessel. The exterior of the vessel will be washed and internal compartments rinsed and washwater flushed into the washwater containment barge. Once the the cleaning and discharge process is completed, the barge will be moved and docked safely out of the way of vessel traffic. The cleaned vessel will be lowered back into the canal. A washwater barge and tugboat would be required on both sides of the summit canal to clean boats heading in both directions. Refer to **Figure 24** below for a general layout plan of Alternative 5.

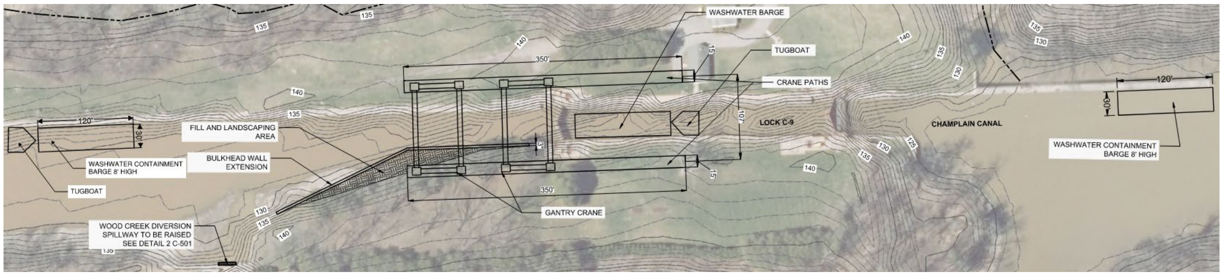


Figure 24. Alternative 5 General Layout Plan.

Large cargo vessels that are greater than 100-ft long will continue to utilize Lock C9 for passage; however, no water treatment method is provided. This alternative does not impede boat traffic throughout the canal and significantly reduces the exchange of water between the Hudson River basin and the Lake Champlain basin for boats less than 100 feet long. Lock gate seals would also be repaired. Alternative 5 would allow less water to pass between the Hudson and Champlain watersheds than Alternative 4 as the locks would only be opened for commercial traffic.

Summary of Alternative 5 Implementation:

- Raise weir elevation at the Wood Creek Spillway
- Construct a conduit to re-route excess water back into the Hudson River Basin at Lock C8
- Install large boat lift
- Procure and install boat wash mechanical systems; water heater, pressure tanks, hoses, spray guns
- Procure a large barge for washwater containment
- Procure a tugboat to propel washwater barge
- Repair seals on lock gates
- Permits / approval from the NYS Historic Preservation Office may be required when modifying Champlain Canal features
- Would be constructed within NYSCC right-of-way; no additional land or easement acquisition required
- Effectiveness: Alternative 5 would significantly reduce the Hudson River Basin water from entering the Lake Champlain basin and would not impede large vessel traffic through the canal. This addresses transfer of AIS in water and conveyed via boat (hull or bilge water). These goals are achieved by greatly reducing the need to allow vessels smaller than 100-ft long to pass through Lock C9, while still preserving the possibility for larger commercial vessels to pass through Lock C9 when necessary.

4.3 Comparative Construction Costs

Rough order of magnitude construction cost estimates were prepared using RS Means database and cost quotes from manufacturers for Alternatives 2, 4 and 5 in order to compare the three preferred alternatives on an equivalent cost basis. The detailed cost estimates are included in Appendix G. The general assumptions of the cost estimate are listed below:

1. Costs do not include allowances for Lands, Easements, Rights-of-way and Disposal or borrow areas (LERDs)
2. Costs do not include the costs of additional studies and surveys needed to bring these plans to a level of completeness for construction ready purposes
3. Costs do not include operations and maintenance costs over the lifetime of the project
4. Costs do not include additional staff or training required for operating boat lift equipment
5. Costs do not include delivery and installation of the cranes/boat lifts.
6. Costs do not include new electrical utility access or other utility connections
7. Costs do not include any demolition or excavation costs
8. Assumed that all work to be completed within the canal can be performed while dewatered (costs exclude any construction dewatering and water management)

The cost estimates only consider the physical construction features depicted in the concept plans. Due to the unknown timeline to project construction, the cost estimates are based on price levels as of the date of this report and not projected to the mid-point of construction, as is usual practice.

Alternative 2 construction cost estimate is valued at $18.3 million; this does not include the exceptions noted above, nor does it include the cost of the overland bypass to reroute goods previously carried by cargo vessels via the canal system.

Alternative 4 construction cost estimate is valued at $2.4 million; this does not include the exceptions noted above.

Alternative 5 construction cost estimate is valued at $11.4 million; this does not include the exceptions noted above.

The primary project goals are to first reduce or eliminate the transfer of AIS between the Hudson River and Lake Champlain basins, and secondly to still accommodate boat traffic across the summit canal. **Table 9** below provides a comparison of the first cost of construction and the effectiveness of meeting project goals.

Table 9. Comparison of Preferred Alternatives			
Alternative	Construction Cost	Reduction of AIS Transfer Risk	Accommodation of canal traffic
Alternative 2 Berm Structure	$18.3 Million	Greatly reduced (most effective)	Obstacle to large cargo vessels
Alternative 5 Large Boat Lift	$11.4 Million	Significantly Reduced (2^{nd} most effective)	Full passage of all vessels
Alternative 4 Small Boat Lift	$2.4 Million	Moderately reduced (least effective)	Full passage of all vessels

4.4 Multi-Criteria Decision Analysis (MCDA)

USACE ERDC prepared a Multi-Criteria Decision Analysis (MCDA) for this project to evaluate the alternatives asking stakeholder to characterize and compare alternatives for a canal barrier system to impede aquatic invasive species (AIS) from passing between the Hudson River and Lake Champlain watersheds through the Champlain Canal. The comparison uses decision criteria which are weighted for importance and then scored for each alternative. The criteria scores sum to the overall score for each alternative.

The MCDA model uses the equation:

$$\sum_{cc} (weights_{sc} * scores_{sc})_{cc} * weights_{cc}$$

Where:

sc = sub-criteria

cc = criteria categories

Using criteria provided by stakeholders in the June 2020 stakeholder engagement meeting, ERDC refined a hierarchal structure of six overarching criteria, and 23 sub-criteria which were defined over time with subsequent input. In the fall of 2020, stakeholders completed a weighting survey to reflect the relative importance of each criterion to the overall decision. The final hierarchy is shown in **Table 10**

Table 10. MCDA Criteria Weight Summary

	Criteria	Weight Within Category	Category Weight	Overall Weight
Environmental Impacts	Increase of water temperature on Lake Champlain Side of Barrier	0.20	0.19	0.04
	Dissolved oxygen on Lake Champlain Side of Barrier	0.24		0.05
	Turbidity after construction on Lake Champlain Side of Barrier	0.24		0.05
	Wetland Impacts by New Water Withdrawals to Maintain Canal Levels	0.32		0.06
Effectiveness at Eliminating AIS risk	Quantity of untreated water that moves between basins	0.37	0.23	0.08
	Percent of uncleaned vessels that move between the basins	0.36		0.08
	Time to implementation	0.27		0.06
Vessel & Boater Accessibility	Is easy to use for boaters	0.50	0.15	0.08
	Additional time that boaters must wait to move between basins	0.50		0.07
Community Impacts	Odor and noise for nearby residents after construction	0.24	0.13	0.03
	Job loss or creation for communities near the barrier	0.30		0.04
	Hazards to human health and safety	0.46		0.06
Broader System Impacts	Historic preservation of existing canal corps assets, modified as needed to address AIS	0.31	0.14	0.04
	Canals Ability to Transport All Boats	0.40		0.06
	Minimizes potential for resource conflicts (water, energy)	0.29		0.04
Operation and Maintenance Requirements	Maintains operating conditions despite extreme events (flood, drought)	0.27	0.16	0.04
	Energy use	0.23		0.04
	Operations and maintenance requirements	0.26		0.04
	Need for security measures	0.24		0.04

A subset of stakeholders volunteered to participate in the Technical Committee which devised value functions to score each criterion on a 0.00 t0 1.00 scale and performed the scoring.

Alternatives 2, 4, and 5 were evaluated as well as a Future Without Project (FWOP) condition. A graph summarizing the final ratings for these four conditions is provided below.

4.4.1 Alternatives Scoring

The bar chart below shown as **Figure *25*** provides a comparison of the MCDA scoring for the three top selected plans and the Future Without Project (FWOP) plan.

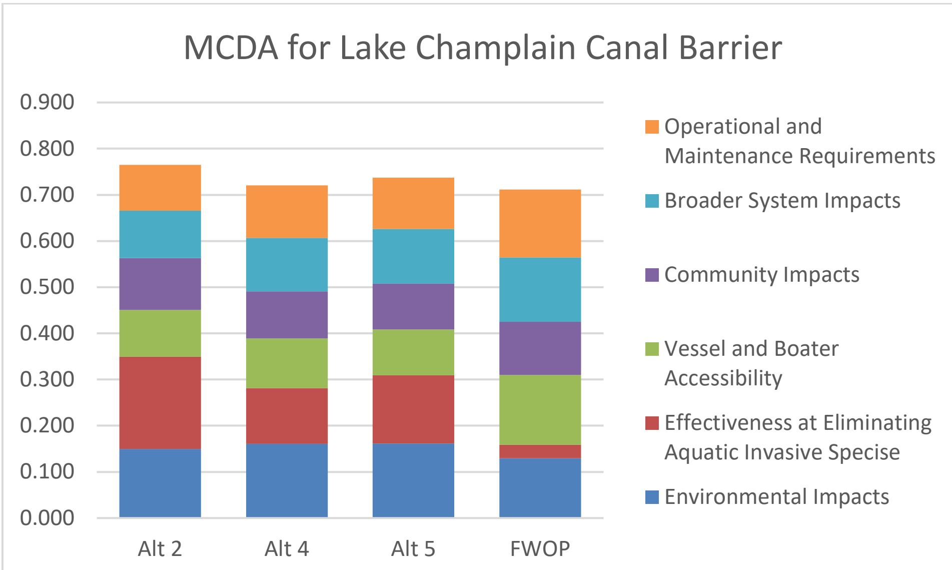


Figure 25. Comparison of MCDA for top Selected Alternatives and FWOP

Alternative 2 scored highest, with a score of 0.765 out of 1. Refer to **Appendix H** for more detail regarding the MCDA process and evaluation.

4.5 Cost-Effectiveness and Incremental Cost Analysis

The USACE ERDC prepared cost-effectiveness and incremental cost analyses (CEICA) to support decision-making and planning in the Champlain Canal Invasive Species Barrier Study by comparing costs and benefits of alternatives 2, 4, 5, and a FWOP scenario.

The objectives of the CEICA were to screen plans and select the most economically efficient plan, also known as the recommended plan. To accomplish this, plans were screened to identify the subset of plans which are the most viable (cost-effective analysis), and then from the cost-effective plans identify the best buy plans (incremental cost analysis). The CEICA was performed by comparing non-monetary environmental benefits, obtained from the MCDA to monetary costs of alternatives. In this first step, alternatives were most efficient at providing environmental benefits on a per cost basis. Alternatives were not considered cost-effective and eliminated if they met any of these criteria:

1. The same output produced by the alternative can be produced by a different plan at lower cost.

2. A larger output can be produced by another alternative at the same cost.

3. A larger output can be produced by another alternative at less cost.

Next, the incremental cost analyses were then conducted on the cost-effective alternatives to provide information on the change in cost between alternatives (i.e., the additional costs of selecting one plan vs another). Best buy plans were those which provide the greatest net change in output for the least increase in cost. Best buys are identified by reviewing the incremental cost per unit for each alternative.

The CEICA was performed for both sets of the MCDA results to assess project benefits: 1) the overall weighted benefits from the MCDA: and 2) the effectiveness of the alternatives at removing AIS (the primary project objective). Both sets of CEICA results are presented below. Refer to **Appendix I** for more details.

4.5.1 CEICA Results for Overall Benefits

CEICA was conducted on the overall weighted benefits from MCDA and construction costs for alternatives FWOP, 2, 4, and 5. Results (**Table 10** and **Figure 26**) show that the cost per benefit for each alternative increases as the amount benefit provided increases. However, the cost of Alt5 is greater for the magnitude of ecological benefit it provides; therefore, it was eliminated. The remaining Alt2 has a greater ecological benefit at a higher cost per unit, when compared to Alt4. However, the incremental cost per unit for Alt2, with 6.10% more ecological benefit, is not a lot higher than Alt4 ($266.7/unit Alt4 vs $361.4/unit Alt2).

Table 11. Incremental cost analysis summary for weighted MCDA outputs.

Alternative	Benefit	Cost	Incremental Cost per Unit
FWOP	0.712	0	0
Alt4	0.721	2.4	266.7
Alt2	0.765	18.3	361.4

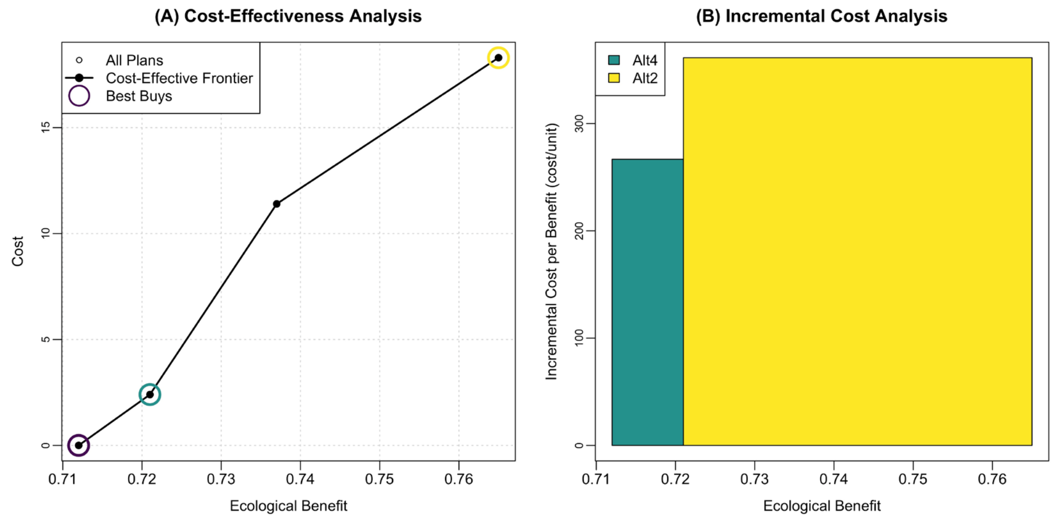


Figure 26. CEICA summary for weighted MCDA outputs.

4.5.2 CEICA Results for Effectiveness at Removing AIS Risk

CEICA was also conducted with only the MCDA weighted scores for effectiveness at removing AIS, obtained from the MCDA, and construction costs for alternatives 2, 4, 5, and FWOP (**Table 11** and **Figure 27**). Alternative 5 was also eliminated. In this case, Alt2 has a much greater incremental cost per unit ($26.1/unit Alt4 vs $201.3/unit Alt2). Thus, Alternative 4 could be identified as a potentially advantageous action through the lens of CEICA. However, the final recommended alternative may depend on the willingness to pay for the amount of benefit provided by the larger alternative (Alt2) and/or other qualitative difference between the plans not captured in either the MCDA or CEICA.

Table 12. Incremental cost analysis summary for weighted AIS MCDA outputs.

Alternative	Benefit	Cost	Incremental Cost per Unit
FWOP	0.029	0	0
Alt4	0.121	2.4	26.1
Alt2	0.2	18.3	201.3

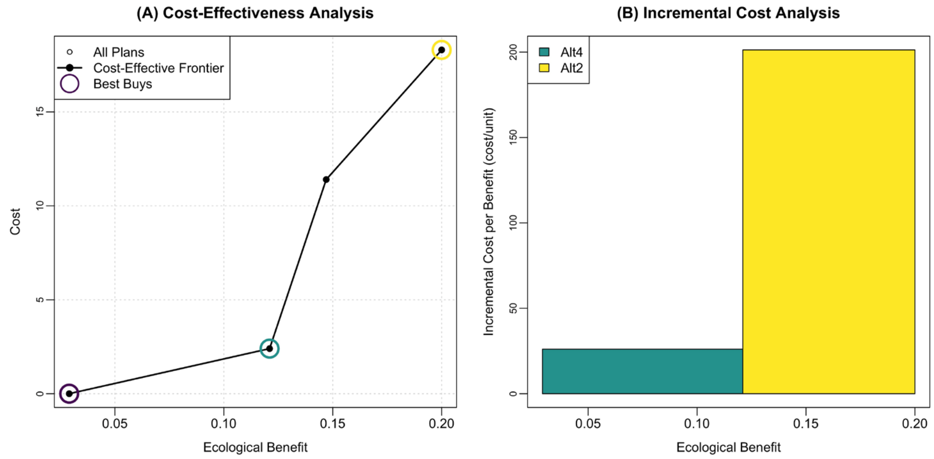


Figure 27. CEICA summary for weighted AIS MCDA outputs.

4.6 Alternative Comparison and Selection

The primary factors for selection of a recommended plan were effectiveness of reducing the risk of transmission of AIS and project cost. In the CEICA analysis, it was shown that Alternative 2- Physical Barrier and Alternative 4- Small Boat Lift were cost effective, best buy plans because the unit cost increases linearly as the magnitude of benefits increases. Best buy plans produce the greatest increase in value at the lowest cost and are typically considered candidates for recommendation in a USACE feasibility study. While Alternative 2 was the most expensive option, it also provided the most benefits for the removal/prevention of AIS transfer and did so at a favorable cost/benefit ($361.4/unit Alt 2) especially when compared to Alternative 4 ($266.7/unit). Alternative 5- Marine Boat Lift, was not identified as a best buy plan and therefore was not considered for recommendation. The marine boat lift in Alternative 5 would be able to handle a good portion of Champlain Canal vessel traffic without opening the lock, making it more effective than Alternative 4 at eliminating AIS risk. However, Alternative 5 relies on a large boat lift, wash water barges, and tugboats to collect decontamination procedure water and it was therefore not cost effective. Alternative 5 may not have received higher benefit scores than Alternative 4, because benefit scoring assumed that providing a portage option for vessels was considered fulfillment of the project objective for navigability. Put differently, the boat size limitations of Alternative 4 were not a detriment to its benefit score. In addition, Alternatives 4 and 5 include an aspect of implementing seasonally restricted low-risk lockage for commercial and maintenance vessels, which may be challenging to enforce.

Other considerations were used to determine the recommended plan since both Alternatives 2 and 4 were best buy plans. The small boat lift recommended for Alternative 4 can accommodate vessels up to 30-40 feet. Canal usage data in Table 4 shows that approximately 42% of vessel traffic is over 40 feet in length and would require portage with boat lift, with up to 20% of commercial and maintenance traffic (Table 3) still requiring lockage. Most importantly, Alternative 2 provides robust protection from AIS transfer between the Lake Champlain and Hudson River watersheds by creating a hydrologic separation within the Champlain Canal that would stop the flow in the canal in both directions. Alternative 2 is the only alternative that prevents direct water transport of AIS between the watersheds and for this reason it is the preferred alternative for the non-federal sponsor

Alternative 2- Physical Barrier, consists primarily of a new berm across the canal, creating a new conduit to re-route excess water back into the Hudson River Basin near Lock C8, raising the weir at the Wood Creek Spillway, providing a small boat ramp and a large boat lift, and a cleaning station at the berm to allow for most boat traffic to continue along the canal. The recommended combination of measures in Alternative 2 reflects a “best buy” plan as identified using CE/ICA (Appendix I). Implementation of Alternative 2 will meet the planning objectives of this project by-limiting AIS transfer along the Champlain Canal, having a favorable cost to benefit ratio and accommodating the needs of the stakeholders along the Champlain Canal. Alternative 2 has therefore been designated the recommended plan.

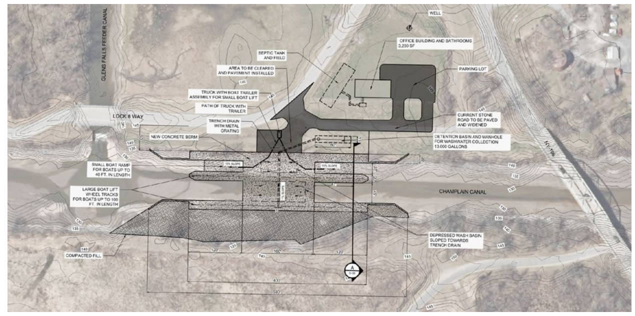
5 Recommended Plan

The successful functioning of Alternative 2 will require that the local stakeholders assume an active role in the operation and maintenance of the constructed project. The ability to properly operate the small boat ramp, large boat lift and other aspects of this alternative will require specialized training for operation, maintenance, as well as safety.

The primary features included in this plan are as follows:

Alternative 2 – Summary of Measures, Physical Barrier Plan:

- Measure 1) Reverse Flow C9 -> C8, (Raise Weir),
- Measure 2) Back Pump,
- Measure 4) Physical Barrier (Berm / Block Flow),
- Measure 5) Boat Lift and Cleaning Station, and
- Measure 9) Repair Lock Seals



Recommended Plan, Alternative 2, Physical Barrier Plan

In order to keep the protection measures in their design condition, Operations and Maintenance protocol must conduct periodic inspections of all facilities and make repairs or replacements as necessary. Additional studies are required to validate the findings of this initial planning study including but not limited to: Hydrologic Evaluation for Stream capacities / Canal Makeup Water, Full Topographic and Utility Survey, Boundary/Easement Survey, Traffic Studies, Geotechnical investigation at the location of the proposed concrete berm, feasibility study from/with NYSCC regarding the proposed transfer station, and a NEPA analysis. These studies would be needed to determine the boundaries of the project, the suitability of the recommended design, as well as any potential impacts on the local communities and interests. It is the joint recommendation of the study team that the Recommended Plan developed in this study be taken to the next level of design analysis and development to verify this approach.

6 Next Steps

6.1 Phase II Study

Following the completion of the Phase I portion of the study, the non-federal sponsor may choose to move forward with the findings of the study independent of USACE. The non-federal sponsor may also choose to continue to work with USACE and execute a Design and/or a Design/Construction Project Partnership Agreement (PPA) under the Lake Champlain Program Section 542 authority. In this scenario the Phase II portion of the study would consist of detailed analyses of alternatives including engineering studies such as hydrologic evaluation for stream capacities / canal makeup water, geotechnical investigations at the location of the proposed concrete berm, topographic / utility survey as well as boundary / easement survey, vessel traffic studies through the canal, detailed cost estimates and NEPA compliance. There will also be determination from NYSCC regarding feasibility of the proposed transfer station, Hydro-plant, and unobstructed commercial and material passage through the canal.

6.2 Construction

The Canal Barrier Project can be constructed under the Lake Champlain under WRDA 2000, Section 542 authority. If a project goes into construction with USACE assistance, an Environmental Assessment and Finding of No Significant Impact or an Environmental

Impact Statement and Record of Decision, and all applicable environmental laws and regulations will be complied with.

The Lake Champlain Program is authorized for $32M for planning, design and construction. The New York District has received $8.83M to date. At this early phase of the Canal Barrier project, the construction cost estimate is $18.3M and will likely go up after the Phase II analyses. It may be a challenge to receive this amount of funds in the Lake Champlain Program given that Environmental Infrastructure programs are not a priority for the Administration. It is anticipated that future WRDA bills may increase the amount authorized for the Program.

Another option for construction of the project is that the non-federal sponsor may choose to work with USACE under the WRDA 2007, Section 5146 authority (which provides for construction to be 100% federally-funded). Federal funds have not yet been appropriated for this authority. Pursuing construction under this authority would require Congress to appropriate funds to the authority, and once funds have been appropriated, USACE Headquarters to issue Implementation Guidance and a new PPA. A new Feasibility Study may be required to pursue construction under this authority. The non-federal sponsor would need to work with their Senators and/or elected officials to have funds appropriated for this authority. Cited below are the relevant passages from WRDA 2007, Section 5146;

SEC. 5146. LAKE CHAMPLAIN CANAL, VERMONT AND NEW YORK.

(a) Dispersal Barrier Project- The Secretary shall determine, at Federal expense, the feasibility of a ***dispersal barrier*** *project at the Lake Champlain Canal, Vermont and New York, to prevent the spread of aquatic nuisance species.*

(b) Construction, Maintenance, and Operation- If the Secretary determines that the project described in subsection (a) is feasible, the Secretary shall construct, maintain, and operate a dispersal barrier at the Lake Champlain Canal at Federal expense.

6.3 USACE Process for Next Phase

- Final Report Completion (Phase I) – March 2022
- Phase II Study or Study/Design – Section 542 Projects Need Approval by Lake Champlain Basin Program (LCBP) Steering Committee – ***Approved Dec 2021***
- Prepare Project Partnership Agreement (PPA) Package - (6 – 8 Weeks)
- Develop Scope of Work
- Prepare Project Management Plan (PMP)
- Require Sponsor Support Documentations & Non-Fed match for the project
- PPA Package Approval at North Atlantic Division (NAD) - (4-6 Weeks)
- Start of Phase II Study– May finish in 18 – 24 Months. Study/Design may take longer, up to 36 months.
- Following Completion of Phase II Study or Study/Design, another PPA will be required for Construction and will follow same process for PPA execution.

7 References

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8 Appendices

Appendix A – Water Resources development Act 2000, Section 542 – Lake Champlain Watershed

Appendix B - Plans of Record

Appendix C – Invasive Species Inventory Report and Matrix

Appendix D – Site Visit Notes and Photos

Appendix E – Alternative Plan Layouts

Appendix F – Preferred Alternative Concept Plan Layouts

Appendix G – Preferred Alternative Cost Estimates

Appendix H – Multi-Criteria Decision Analysis Report *(prepared by the USACE)*

Appendix I – Champlain Canal Invasive Species Barrier Study Cost-Effectiveness Analysis and Incremental Cost Analysis *(prepared by the USACE)*