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UNITED STATES FISH AND WILDLIFE SERVICE
Lake Champlain Fish and Wildlife Resources Office

Feasibility Study of Control Methods for Prevention of Spiny Water Flea Spread from Great Sacandaga Lake to Lake Champlain

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

HDR

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I. INTRODUCTION

Purpose

World-wide human-mediated spread of nonindigenous aquatic organisms is one of the greatest threats that aquatic ecosystems face today. Nonindigenous species (NIS), also called exotic, alien or non-native species are generally referred to as those plants, animals, and other organisms that are found beyond their natural geographical ranges (US Congress, OTA 1993). It is estimated that as many as 50,000 nonindigenous species have been introduced into the United States, either intentionally or unintentionally, some with harmful effects. In more specific terms, an invasive species is one category of NIS that is defined as 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112 1999). A sub-classification of invasive species are the Aquatic Nuisance Species (ANS) described as nonindigenous species that threaten the diversity or abundance of native species; the ecological stability of infested waters; commercial, agricultural, aquaculture and recreational activities dependent on waters (US Congress 2000). One aquatic nuisance species known as *Bythotrephes longimanus* (spiny water flea), which has recently been discovered within Great Sacandaga Lake located in New York, has the potential for causing economic hardship and environmental harm to the lake, associated river ecosystems, and other regional lakes.

There are reported occurrences of spiny water flea (SWF) within other lakes and reservoirs in New York according to the U.S. Geological Survey's (USGS) Nonindigenous Aquatic Species (NAS) database (USGS 2009). With these documented occurrences, there is concern that infestation of streams and rivers could also occur leading to increased dispersal throughout the state and ultimately into Lake Champlain. While no documented cases of SWF exist in the Sacandaga and Hudson Rivers below Great Sacandaga Lake, if dispersal into these rivers does occur, the Glens Falls Feeder Canal could become a direct SWF pathway to the Champlain Canal which in turn flows to Lake Champlain.

As documented in a draft report, a technical work group from the New York State Canal Corporation and Lake Champlain Basin Program Partnership was formed to investigate options to prevent the transfer of SWF from the Hudson River drainage to Lake Champlain, which is in the St. Lawrence River drainage (Surprenant 2009). The inter-disciplinary team was comprised of staff from the New York Department of Environmental Conservation, the Lake Champlain Basin Program, the Lake Champlain Sea Grant and the New York State Canal Corporation. The work group conducted a literature review and contacted agency and industry professionals for information regarding the biology and potential negative effects of SWF and treatment options. The work group concluded there were potential treatment technologies available to restrict the movement of the SWF, but further review into the feasibility, construction and costs would be required.

The U.S. Fish and Wildlife Service, Region 5 received funding through a special appropriation to the Great Lakes Fishery Commission to investigate options to protect Lake Champlain and its watershed from nonindigenous species. This study, entitled **Feasibility Study of Control Methods for Prevention of Spiny Water Flea Spread to Lake Champlain,** has been developed in response to a request from the Service's Lake Champlain Fish and Wildlife Resources Office.

Scope of Work

This study reviewed existing literature for the biology and life stages of the SWF and evaluated the likelihood of in-water transport of SWF from Great Sacandaga Lake to Lake Champlain. In addition an analysis of the potential technologies that may be effective in managing and intercepting the SWF from both an environmental and engineering point of view was to be provided. The specific goal was to provide the USFWS with an objective analysis of the effectiveness of these technologies in preventing the in-water transport of SWF to the Champlain Canal, and ultimately Lake Champlain.

This study includes an assessment of the potential spread and impacts of the SWF, management options to limit dispersal, the effectiveness of potential technologies in limiting dispersal of the SWF, and the advantages and disadvantages of each technology. Although existing flow rates, water levels, and drainage were considered in relation to effectiveness and feasibility of each technology, evaluating the effect of specific operational changes (e.g., restricting flow or adjusting water levels) to limit SWF dispersal was not the intent of this study.

II. EXECUTIVE SUMMARY AND RECOMMENDATIONS

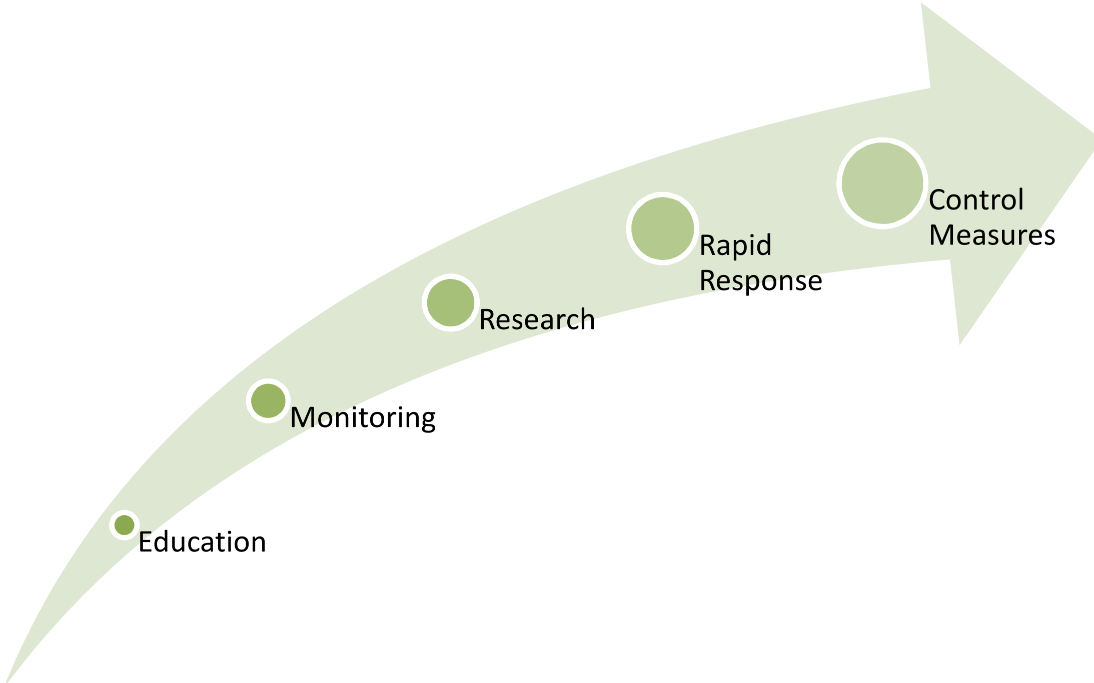
Study Overview

In October 2008, the spiny water flea (*Bythotrephes longimanus*) (SWF) was confirmed as being present in Great Sacandaga Lake (GSL) located in Fulton and Saratoga Counties, New York. GSL is a 27,000-acre impoundment on the Sacandaga River in the Hudson River drainage that augments flows in the Hudson River. Flows from the Hudson River control the water level of the Champlain Canal via the Glens Falls Feeder Canal (Feeder Canal) creating a direct pathway for SWF dispersal to Lake Champlain. To date, the United States Geological Survey (USGS) maintained Nonindigenous Aquatic Species Database does not indicate any SWF occurrences below the outfall of GSL (USGS 2009).

The primary goal of this report is to evaluate the likelihood of in-water transport of SWF from Great Sacandaga Lake to Lake Champlain and provide an analysis of the potential technologies for limiting the in-water transport of SWF. In order to evaluate the aspects of SWF movement and the likelihood of dispersal, this study provides an overview of the water resources in the region and more specifically, the Champlain Canal (**Section III**). The background of the SWF, including history, physical description, habitat, life history and distribution, is provided in **Section IV**. A review of known treatments along with their advantages and disadvantages is provided in **Section V**, in addition to a review of management alternatives. **Section VI** evaluates potential treatment technologies and provides a recommended set of objectives to be pursued based on possible management alternatives.

Findings and Recommendations

Recommendations below address both the human-mediated and in-water potential for SWF spread. Based on the biology of the SWF and the limited information available at the time of this document, there is a low probability it will spread from GSL to Lake Champlain through the Champlain Canal. Although SWF have been detected in riverine environments, their preferred habitat is a deep lake environment. If detected in the Sacandaga or Hudson Rivers, it is not likely that the SWF would persist long enough to travel an estimated 50 miles from GSL to Lake Champlain. There is a higher likelihood that the SWF will be spread to Lake Champlain by human activities. Objectives to reduce the risk of spread of SWF to Lake Champlain listed below are prioritized based on these conclusions. Figure II-1 provides a roadmap to reducing the risk of SWF dispersal into Lake Champlain. The roadmap involves a series of steps, some of which are already underway, but it also provides a logical progression to a solution that includes activities in addition to engineered solutions.



Objective 1: Education – Continue and emphasize an educational campaign that informs the general public about SWF and the efforts that are needed to limit spread to Lake Champlain. Established plans such as *Opportunities for Action* (2003), *Lake Champlain Basin Aquatic Nuisance Species Management Plan* (2005), and *State of the Lake* (2008) should provide the framework for this campaign. Many programs are already in place.

Objective 2: Monitoring – Continue implementation of a comprehensive monitoring program to document occurrences of SWF below GSL and the Champlain Canal. Although the LCBP Long Term Biological Monitoring Program currently samples for SWF in the Feeder Canal and Champlain Canal, an increased monitoring effort including additional locations and increased sampling frequency should be considered because early detection is critical. This effort should also include a formalized reporting sequence for tracking the movement of SWF.

Objective 3: Research - Conduct further research so that potential technologies to limit the in-water spread of SWF can be adequately evaluated. After an exhaustive literature review, it is apparent that further research targeting mortality of the SWF, adaptation to riverine environments, etc. is necessary. Future research will hopefully provide more information related to SWF mortality under various chemical and physiological conditions.

Objective 4: Rapid Response – Develop a rapid response protocol specific to spread of SWF from Great Sacandaga Lake to Lake Champlain through the Glens Falls Feeder Canal and Champlain Canal. Although a rapid response protocol for the Lake Champlain Basin has been developed, it may be beneficial to develop specific actions that outline a critical control point and potential control methods to be implemented once the SWF has approached that critical control point. The process of implementation would only occur if and when SWF is detected at the selected critical control point.

Objective 5: Control Measures – Implement control measures that limit the human-mediated and in-water spread of SWF to Lake Champlain. Control measures targeting human-mediated spread of SWF such as cleaning stations and inspections at boat launches should be considered. Technological control methods that limit the in-water spread of SWF from Great Sacandaga Lake to Lake Champlain should be revisited after further research is conducted and implemented only if SWF is detected at a critical control point to be determined. Based on available literature, it is recommended that a physical barrier such as a permeable barrier or rotating drum/disc filter may be the best alternative based on cost, effectiveness and potential environmental or recreational impacts. This recommendation should be revisited as further research becomes available for potential unproven technologies that may be applicable for SWF spread. For instance, further research into carbon dioxide application may prove its feasibility.

To adequately address the spread of SWF, all objectives will require implementation on varying timelines. It is evident that there is a correlation between the spread of SWF and human activities, i.e., commercial shipping and recreational boating. To this end, it is important that the public becomes cognizant of how they can affect further dispersal of the SWF. This is and should continue to be an on-going process. Monitoring is an integral part as it establishes a timeline of when the species occurs and how fast it disperses. This can help determine where and how fast control strategies need to be enacted as identified by a rapid response plan. Similar to outreach and education, monitoring is and should continue to be an on-going process. Potential control strategies to limit the spread of SWF have been identified and will require prior budgetary support to implement in a timely manner. As the risk for dispersal into the canal becomes more realized and if it is deemed necessary, it is recommended that appropriate funding be obtained to implement the planning, design, permitting, and ultimately the installation of a physical or chemical barrier system that best meets the requirements for control as outlined in **Section VI**. While preliminary recommendations have been provided herein, further research should be conducted to explore and determine other possible technologies, such as carbon dioxide application. If control measures are implemented, they will also prevent the spread of other aquatic nuisance species.

III. SITE OVERVIEW

As mentioned in the introduction, there is a direct pathway between Great Sacandaga Lake (GSL) and Lake Champlain via the Feeder Canal, which connects the Hudson River to the Champlain Canal (**Figure III-1**). Water discharged from GSL enters the Sacandaga River, which flows into the Hudson River. The Feeder Canal, located off of the Hudson River downstream of its confluence with the Sacandaga River, augments flow in the Champlain Canal by diverting water from the Hudson River. The Champlain Canal connects the Hudson River with Lake Champlain.

The following section provides a brief regional overview of water resources and water quality, as well as an overview of the Champlain Canal and Glens Falls Feeder Canal specifically. The description of the Champlain Canal is only intended to highlight characteristics relevant to this study rather than provide a comprehensive assessment.

Figure III-1. General Project Area

Regional Overview

Water Resources

The Hudson River originates in the Adirondack Mountains at Lake Tear-of-the-Clouds and flows south to its confluence with the Sacandaga River. The Sacandaga River originates in the Highlands of the Adirondacks and is a principal tributary of the Hudson River. Great Sacandaga Lake is a 42 square mile man-made reservoir, approximately 29 miles long, located in Fulton and Saratoga Counties (**Figure III-2**). The average depth is 40 feet, maximum depth is 90 feet at the dam and normal pool elevation is 771 feet msl. It is located west of the Hudson and Sacandaga River confluence and is regulated by the Conklingville Dam, constructed in 1930 in the Town of Day. Since GSL is used for flood control and for low flow augmentation in the Lower Hudson River, mandated flows are released from the Conklingville Dam in sufficient volume to provide a minimum combined flow of 3,000 cfs downstream of the confluence of the Hudson and Sacandaga Rivers (Erie 2001). The Hudson River is approximately 315 miles long and drains into the Upper New York Bay after joining with the Mohawk River north of Albany.

Figure III-2. Great Sacandaga Lake

The Glens Falls Feeder Canal originates at the Feeder Dam on the Hudson River and augments flow to the northern portion of the Champlain Canal, which flows into Lake Champlain and down to the Hudson River (**Figures III-3 and III-5**). Lake Champlain is a 440 square mile natural lake, approximately 110 miles long, located in multiple counties in northeastern New York, northwestern Vermont, and southern Québec, Canada (**Figure III-1**). The average depth is 64 feet, maximum depth is 400 feet and normal pool varies seasonally from about 95 to 100 feet above mean sea level. The lake drains into the Richelieu River which flows into the St. Lawrence River downstream of Montreal.

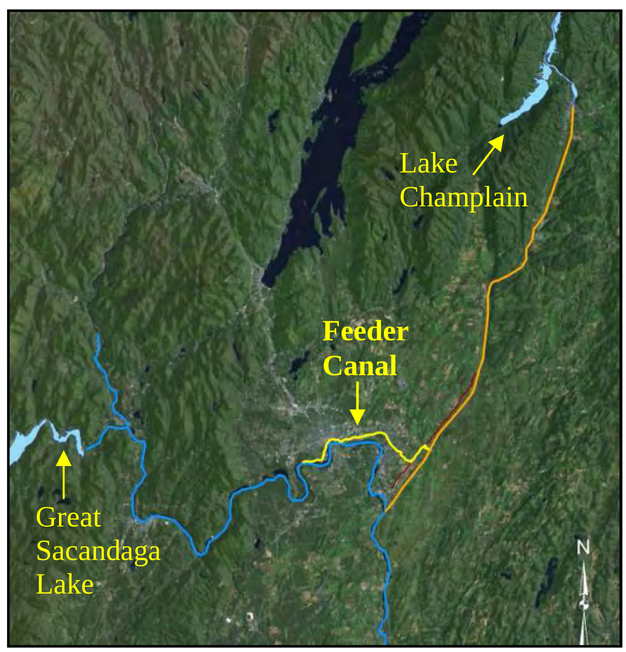


Figure III-3. Regional Hydrology

Water Quality

The Sacandaga River and the Hudson River are part of the Upper Hudson River subbasin, which is about 3,600 square miles and generally has good water quality (Erie 2001). The source of water in this region, the Adirondack Highlands, yields nutrient poor, low alkalinity, and low conductivity water with minimal contamination from human origin. Water quality for the Feeder Dam impoundment generally complies with standards for DO (average 5.0 mg/L and no less than 4.0 mg/L) and pH (6.5- 8.5). The following water quality values for the Glens Falls impoundment are reported: DO values greater than 8.0 mg/L and pH between 6.5 and 6.9. Overall, water quality within and downstream of the Feeder Dam meets state water quality standards (Erie 2001).

Champlain Canal Overview

Champlain Canal Characteristics

The Champlain Canal is part of the New York State Canal System. It was opened in 1823 and ran from Troy to Whitehall, connecting the Hudson River to Lake Champlain (**Figure III-1** and **III-5**). It was originally 40 ft wide, 4 ft deep, and had 24 locks (Malchoff et al. 2005). Modifications between 1860 and 1962 deepened and widened the canal, and reduced the number of locks. The present-day Champlain Canal is 60 miles long and has a minimum depth of 12 feet. There are 11 state-owned locks on the canal, which are numbered 1- 12 skipping the number 10 (**Figure III-4**). An additional federal-owned lock is situated at Troy and joins the Hudson River to both the Champlain and Erie Canals. The Champlain Canal flows south from Lock 8 near Fort Edwards to the Hudson River over an elevation of 134 feet, and north from Lock 9 toward Lake Champlain over an elevation of 54 feet (**Figure III-6**). An average seasonal flow augmentation of 250 cfs and a maximum of 500 cfs is provided by the Glens Falls Feeder Canal (Suprenant 2009).

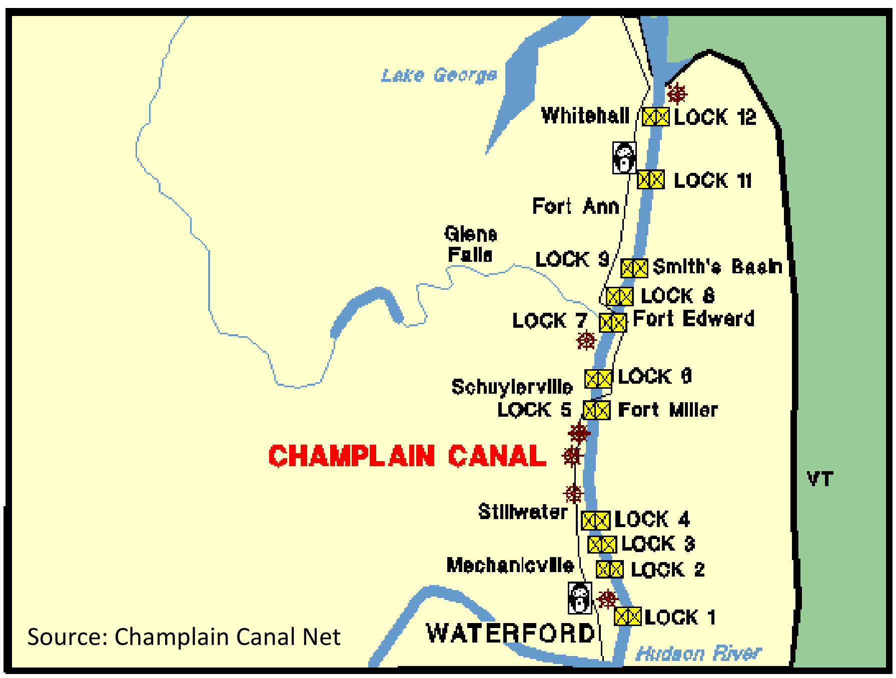


Figure III-4. Champlain Canal Locks

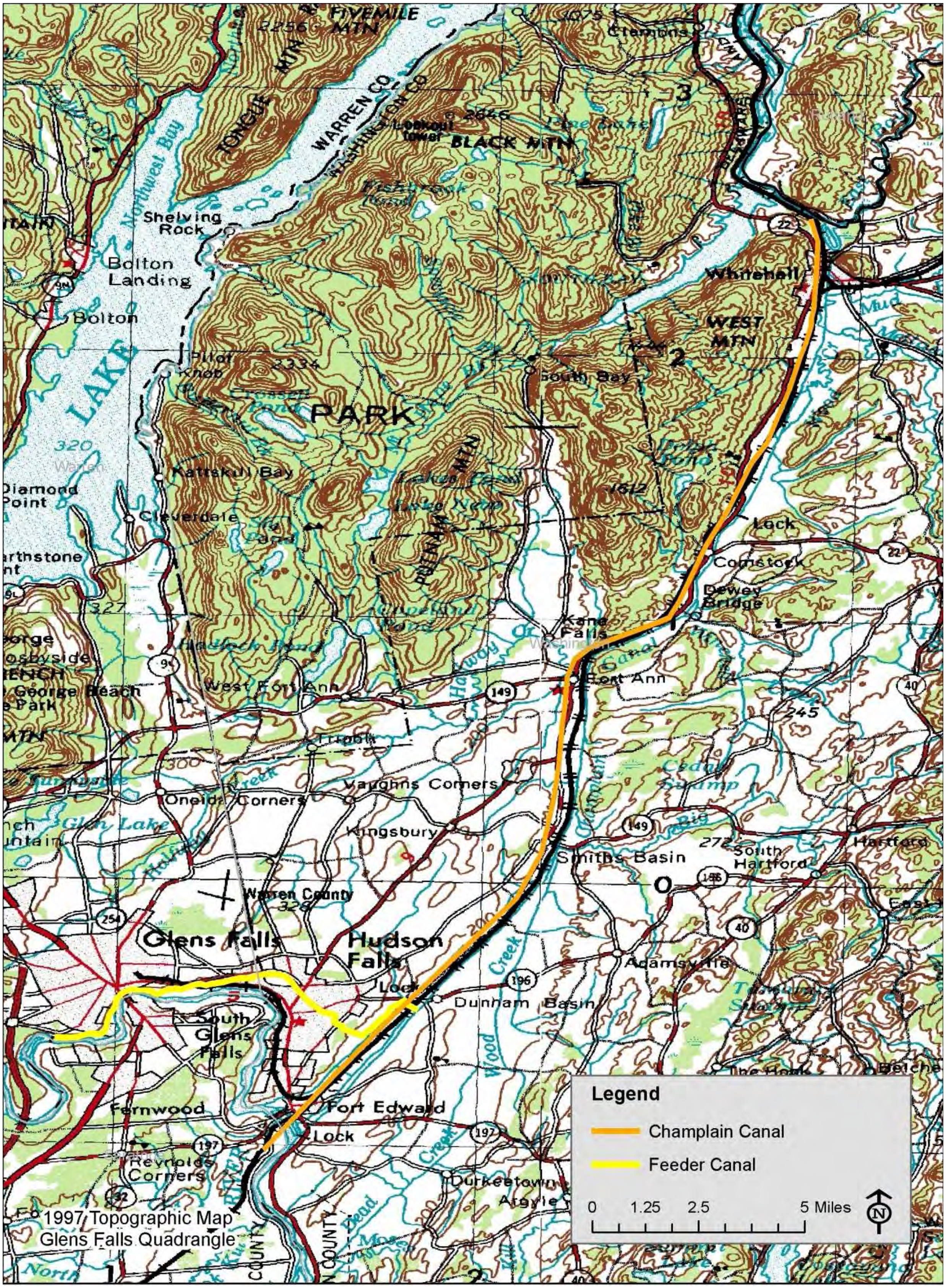


Figure III-5. Champlain Canal Topographic View

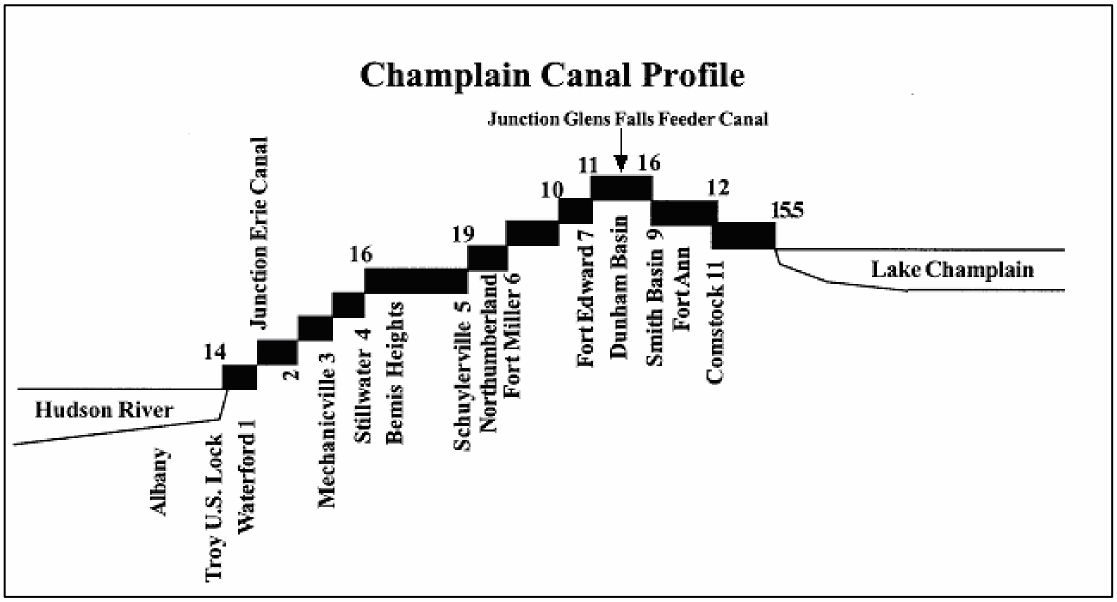


Figure III-6. Champlain Canal Profile

Source: Malchoff et al. 2005

As with the rest of the New York State Canal System, the Champlain Canal has transitioned largely to a recreational and historic resource (Malchoff et al. 2005). The Canal System opens to navigation on May 1st and closes on November 15th each year. Locks operate daily for recreational vessels and on a 24-hour schedule by request for commercial. Commercial shipping (as defined by commercial tonnage) on the Champlain Canal has declined to negligible levels in recent years. Cumulative vessel lockings for commercial traffic still numbers in the thousands, however, suggesting significant amounts of intra-canal traffic between Waterford and Whitehall (Malchoff et al. 2005). Vessel lockings data also underscore the transition from a cargo transportation system to that of a recreational or tourism based system.

Glens Falls Feeder Canal Characteristics

The Glens Falls Feeder Canal originates at the Feeder Dam on the Hudson River at South Glens Falls and ends approximately 8 miles northeast in the Champlain Canal at Hudson Falls between Locks 8 and 9, as shown in **Figure III-7** (Suprenant 2009). The Feeder Canal was originally constructed in 1822 and served as a transportation route for people and goods until 1928 (Alliance 2009). The original canal was 4 feet deep and 28 feet wide. Locks were 90 feet long and 15 feet wide (Alliance 2009 and Percy 2002). It was widened and deepened in 1832, including construction of 13 locks over an elevation change of 130 feet. The Five Combines (Locks 6- 10 located east of Hudson Falls) were constructed in 1845 to accommodate a water level drop of 55 feet. These locks are 15 feet wide and 100 feet long. The present day Feeder Canal provides recreational opportunities but more importantly provides water from the Hudson River to the highest point of the Champlain Canal. The Feeder Canal is drained to the Hudson River through gates ("wickets") and shut down during the winter and for maintenance.

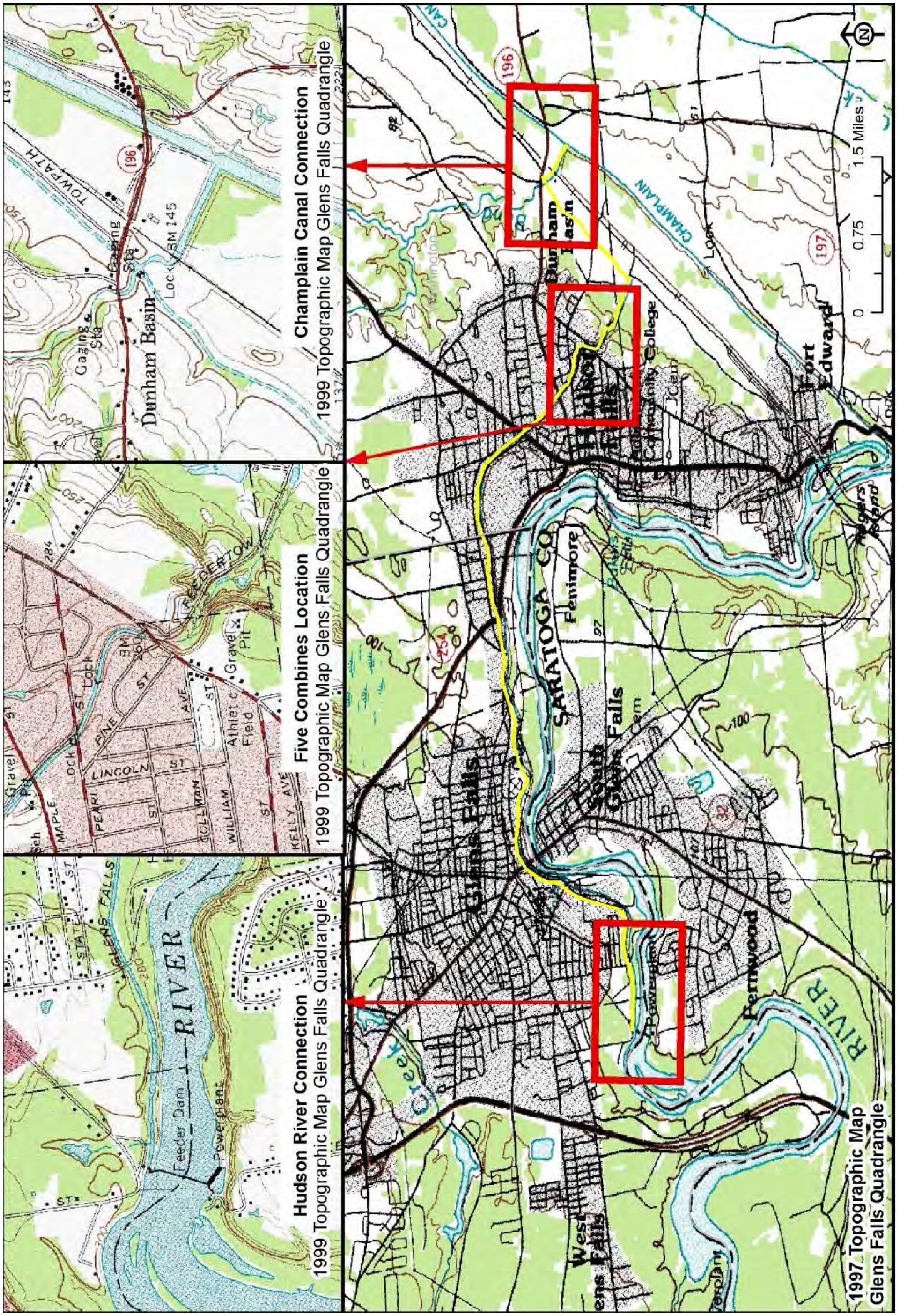


Figure III-7. Glens Falls Feeder Canal- Topo View

IV. REVIEW OF SPINY WATER FLEA BIOLOGY

This section provides a review of the spiny water flea (SWF) (*Bythotrephes longimanus*) biology and includes: a historical overview, physical description and life history traits, ecological and physiological overview, and impact of the SWF on aquatic environments.

Historical Overview

The SWF is native to northern Europe and Asia (Rivier 1998). Its natural distribution ranges throughout the Palearctic from Great Britain to the Bering Sea, but its successful expansion into numerous European lakes (Netherlands, Belgium, and Germany) has made its original distribution difficult to discern (Grigorovich et al. 1998; Ketelaars and Gille 1994). Recent genetic evaluations have identified the Port of St. Petersburg in Russia as the "distinctive donor region" responsible for most of the SWF introductions around the world, including populations in North America (Berg and Garton 1994; Berg et al. 2002). Freshwater infusion into the port from Lake Ladoga and the Neva River has created an avenue for SWF to breach the saltwater barrier that lies between its native and introduced ranges (MacIssac et al. 2000; Ricciardi and MacIssac 2000; Sprules, Riessen and Jin 1990). North American transoceanic vessels that carry grains and other goods to this port take up large amounts of water into the ships ballast after offloading their contents to stabilize and trim the vessel. Invasion and establishment within the Great Lakes was likely an unintentional consequence of ballast water release from an oceanic vessel. The SWF was first discovered in Lake Ontario in 1982. It invaded Lake Huron by 1984 and had become established in all of the Great Lakes by 1987. It has quickly spread to hundreds of lakes and reservoirs.

Spiny water flea is a nonindigenous, nuisance zooplankton that has shown the ability to rapidly colonize new lakes and achieve high densities in short duration. Their presence may exert strong effects on native plankton communities, thus it is extremely important to understand the factors that influence dispersal (Yan and Pawson 1997). The successful introduction and proliferation of SWF in North America can be partially related to the species' tolerance of a wide range of abiotic and biotic conditions within the aquatic environment. These changes have translated into a variety of ecological and economic impacts to lakes and reservoirs across North America.

Physical Description and Life History Traits

Classification and Morphology

Spiny water fleas are taxonomically placed in the subphylum Crustacea (crustaceans) and are members of the Suborder Cladocera, or commonly referred to as the water fleas (**Table IV-1**). The common name, spiny water flea, is derived from the Latin species name "*longimanus*" that refers to the long, barbed tail spine that comprises up to 70% of the total body length (**Figure IV-1)**.

Table IV-1. Taxonomy of the SWF

Taxonomic Levels	Classification	Common names
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Subphylum	Crustacea	Crustaceans
Class	Branchiopoda	Branchiopods
Subclass	Phyllopoda	---
Order	Diplostraca	---
Suborder	Cladocera	Cladocerans or Water fleas
Infraorder	Onychopoda	---
Family	Cercopagididae	---
Genus	Bythotrephes	---
Species	*Bythotrephes longimanus*	SWF

Source: Integrated Taxonomic Information System (ITIS) North America 2009

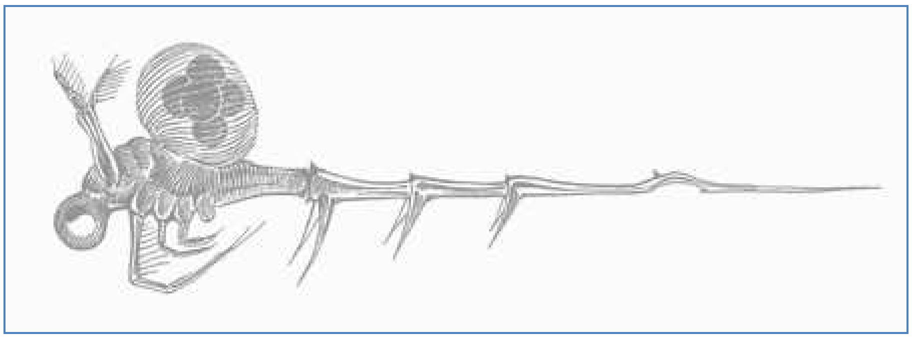


Figure IV-1. Typical Spiny Water Flea line drawing
Source: Ontario Federation of Anglers and Hunters

Early research on the SWF often describes two distinct species: *B. longimanus* and *B. cederstroemi* based on morphological variation. However, recent mitochondrial DNA analysis (Therriault et al. 2002) and more vigorous morphological analysis (Martin and Cash-Clark 1995) has concluded that the SWF is a unique polymorphic species (*B. longimanus)* with two morphological variants. The main difference between the two variants is that *B. cederstroemi* is slightly larger, more robust and possesses an s-shaped bend in the caudal spine. From this point forward, the review includes information that encompasses both SWF variants.

General Characteristics

The SWF is considerably larger than most North American zooplankton species and can reach a maximum size of 1-2 cm (Sikes 2002; Strecker 2007). Spiny water fleas are readily distinguished by their long caudal spine equipped with 1 to 3 pairs of lateral barbs, a large compound eye, and four pairs of prehensile legs (Muirhead and Sprules 2003; Branstrator 2005) (**Figure IV-1**). Gravid females typically possess a large brood pouch that is also readily distinguished (**Figure IV-2**). The number of pairs of lateral spines on the caudal spine is a good indicator for determining the developmental stage and age. Neonates have one pair of lateral spines and gain up to three additional pairs as molting occurs (Ishreyet 1930).

Figure IV-2. SWF Third Instar Female
(Carrying black-eyed stage embryos in brood pouch)
Source: Strecker 2007

Spiny water fleas typically inhabit the upper portion of the water column in large, deep, oligotrophic freshwater lakes (Berg 1992). In addition, they have been discovered in reservoirs, collection basins, canals and rivers within North America. They can tolerate brackish water and are most abundant during the late summer and autumn; however, population occurrences and their relative densities are determined by water temperatures (ranges between 4°C and 30°C) and salinity values (ranges between 0.04 ppt to 8.0 ppt) (Liebig and Benson 2009; Grigorovich et al. 1998).

Habitat Characteristics

Within Europe, the SWF inhabits a wide range of lentic ecosystems that differ dramatically in size, water quality, and fish community structure (Nilsson and Pejler 1973) and it is expected to colonize similar habitats within North America. The preferred habitat of the SWF includes nearly all types of lentic ecosystems including lakes, ponds, and reservoirs; however, there is recent evidence from Minnesota that riverine environments can also provide suitable habitat for populations of SWF to establish (USGS 2009). Typically, the SWF prefers circumneutral conditions (higher conductivity, alkalinity and pH), oligo- to mesotrophic (low-moderate) productivity, and relatively deep lakes (< 100 meters), although it has been found in shallow lakes and ponds, as well as eutrophic lakes (Grigorovich et al. 1998; MacIsaac et al. 2000). It favors the epilimnion of the pelagic zone within lakes and often utilizes the dense, warm layer located just above the thermocline in lakes that are stratified (Barnhisel and Harvey 1995). All instars appear to utilize the upper waters, but juveniles appear to favor deeper waters (Barnhisel and Harvey 1995). Additionally, the SWF demonstrates diel patterns of movement, utilizing the deeper water during the day to avoid predation and migrating to the upper layers during the night where there is abundant food and warmer water (Straile and Halbich 2000).

Geographic Distribution

As mentioned previously, the SWF has become well established within the Great Lakes and has also successfully invaded numerous other freshwater systems within the United States. Invasion and establishment within the Great Lakes was likely the result of an unintentional consequence of ballast water release from oceanic freighters. The SWF first arrived into Lake Ontario in 1982 and within five years the SWF was present in all the Great Lakes. It has continued to spread within a latitudinal band across the northern U.S. and southern Canadian lakes, and currently inhabits dozens of drainage basins within Illinois, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. **Figure IV-3** illustrates the current distribution of the SWF within the United States as reported by the USGS (USGS 2009).

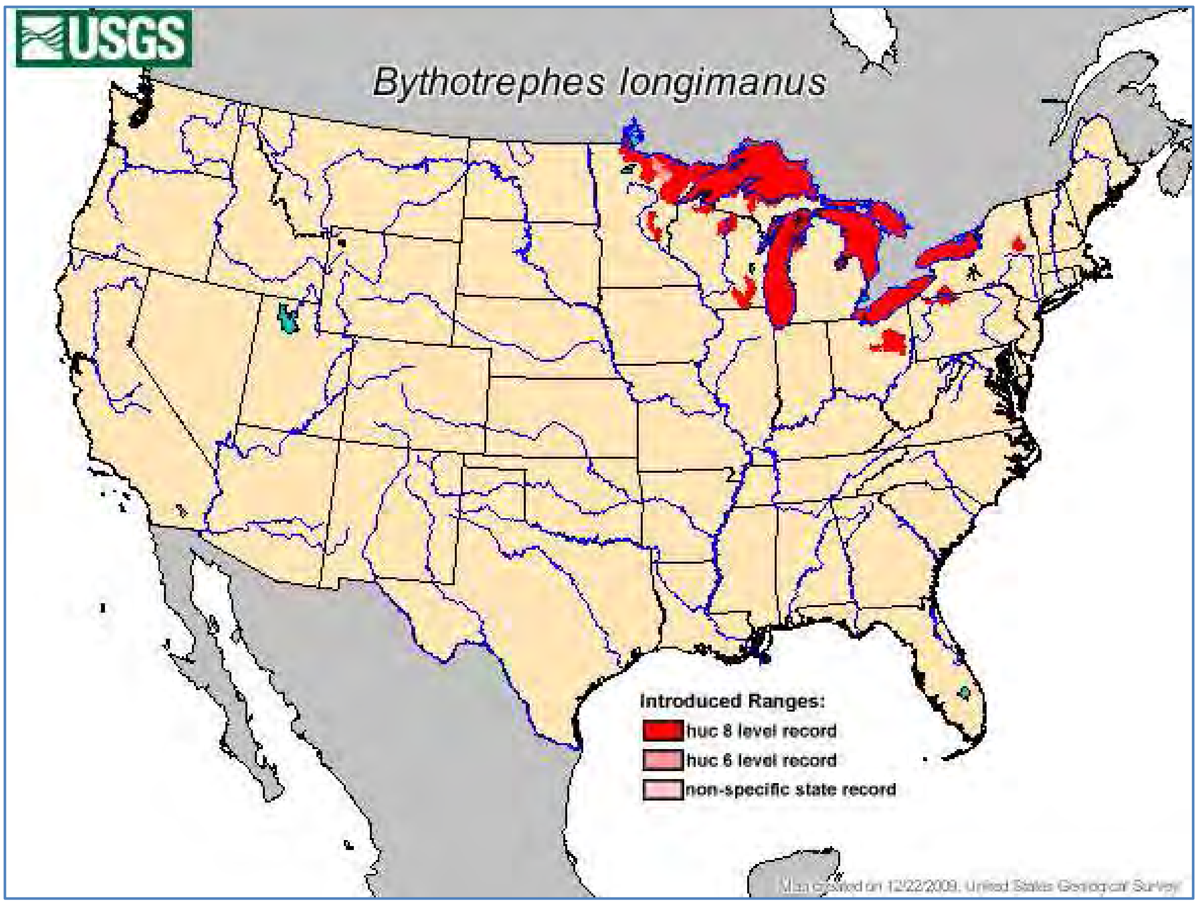


Figure IV-3. United States Distribution of Spiny Water Flea
Source: USGS 2009

Life History

Yurista (1992), Straile and Hälbich (2000), and Branstrator (2005) have performed extensive research and provide comprehensive documentation on the life history of SWF. Generally, the SWF life cycle (**Figure IV-4**) has three main developmental stages: Stage 1-neonate, Stage 2-

juvenile, and Stage 3-adult. Developmental stage is directly linked to the total pairs of barbs located on the caudal spine. Neonates have 1 pair, juveniles have 2 pairs, and adults have 3- 4 pairs. At the onset of Stage 3, the caudal spine will cease growth.

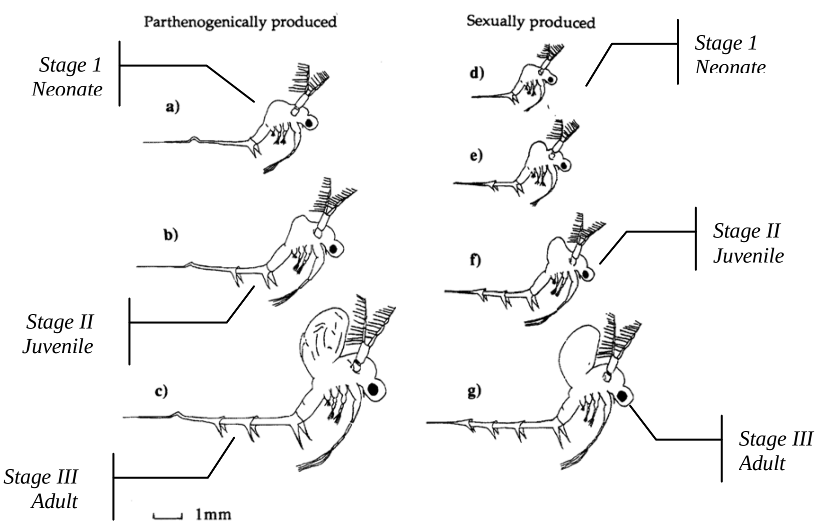


Figure IV-4. Spiny Water Flea Instars
Source: Yurista 1992

Spiny water flea, like many zooplankton, has developed the ability to reproduce both asexually (parthenogenesis) and sexually. As water temperatures rise during the spring (typically mid-May) they hatch from sexually produced "resting" eggs that have overwintered on the lake bottom. Resting eggs typically hatch into female SWF beginning the cycle of parthenogenic reproduction. Once hatched, females rapidly achieve sexual maturity and begin to release their first clutch of eggs after 14 days if water temperatures are 12.7 ºC (Yurista 1992) and approximately 9 days if water temperatures are 21.0 ºC (Lehman and Branstrator 1995). Females produce broods of unfertilized eggs ranging from 2-10 eggs, and carry them in the brood pouch until they develop into genetically identical female offspring (Branstrator and Lehman 1996; Straile and Halbich 2000; Branstrator 2005). Live nenonates are released after about 65 hours (Yurista 1992). Parthenogenesis typically peaks during mid summer and continues as long as the water temperatures are suitable and food is abundant (Lehman and Cáceres 1993; Straile and Halbich 2000; Yan et al. 2001).

The switch to sexual reproduction resulting in the production of resting eggs can vary from year to year, occurring anywhere from late-July to mid-October (Yan et al. 2001). As environmental conditions begin to degrade, females begin to produce both male and female offspring through parthogenic reproduction. The presence of males and the decline in optimal environmental conditions cues the onset of sexual reproduction, producing broods of 2-5 resting eggs. After the eggs become mature, the female releases them and they sink to the bottom where they overwinter until environmental conditions become favorable (Berg 1992; Yan and Pawson 1998; Yan et al. 2001). Golden-brown, resting eggs range in size from 0.25- 0.50 mm and are covered by a thick protective coating that allows them to persist through unfavorable environmental conditions (Berg 1992). Spiny water flea resting eggs are considered to be a transient egg bank (i.e. dormancy is of short duration) as eggs can only persist for one growing season. Resting egg survival and viability is approximately 1 to 1.5 years (Herzig 1985; Andrew and Herzig 1974; Strecker 2007).

Age and Growth

The growth rate of SWF is highly variable and is largely temperature dependant, preferring temperatures between 10-24 ºC; however, they can tolerate temperatures between 4 to 30 ºC (Grigorovich et al. 1998; Strecker 2007). Growth may occur under a broader range of temperature tolerances (5-25 ºC), but rapidly deteriorates at temperatures greater than 26 ºC (Garton et al. 1990). After hatching, SWF displays rapid growth rates reaching Stage III size within 9.2 days at 12.7 ºC (Yurista 1992) and 5.4 days at 21.0 ºC (Lehman and Branstrator 1995). The typical life span of SWF is also highly variable and can range from a few days to a few weeks depending on a range of environmental factors (Berg 1992). Once maturity is reached they cease somatic growth and dedicate all energy to the production of offspring (Branstrator 2005). Stage I nenonates lack a metanapulius stage and hatch with an intact caudal spine and measure nearly 1.6 mm at birth (Yurista 1992). Overall, SWF possesses life history characteristics of a K-strategist, emphasizing large bodied offspring with a high degree of individual fitness per offspring (Branstrator 2005).

Productivity

Since SWF is a recent species to most North American systems, numerous studies have reported dramatic seasonal and annual variation in abundance (Berg and Garton 1988; Yurista 1997; Yan and Pawson 1998). As described above, SWF become active as water temperatures begin to warm, arising from resting eggs in mid to late spring. Population growth is rapid after the initial hatching, reaching maximum abundances in early summer with a steady decline toward the end of the growing season (Straile and Hälbich 2000). In Lake Michigan, during July and September of 2000, Pothoven, Fahnenstiel and Vanderploeg (2003) reported SWF mean densities from the pelagic zone ranging from 4 to 1,326/m^3. These measurements demonstrate the patchiness and variability in SWF population density in North America. Population estimates can also be made without sampling for live individuals. Accurate estimates have been derived from the spatial distribution and rate of accumulation of its diagnostic caudal processes in the sediments (Hall and Yan 1997). Spiny water flea resting eggs found in the sediments of Lake Michigan ranged in density from less then 100/m^2 in shallow waters (20 m) to densities over 5,000/m^2 in offshore waters (> 60 m) (Pothoven, Fahnenstiel and Vanderploeg 2003), indicating the importance of the dormancy stage of SWF.

Dispersal Mechanisms

Numerous potential dispersal mechanisms of SWF have been reviewed in the literature. These dispersal mechanisms can be subdivided into natural mechanisms (e.g., water currents, birds, aquatic insects, and other animals) and human-induced or anthropogenic mechanisms (e.g., artificial waterways, ships and other vessels, fishing activities, amphibious planes, and recreational equipment). Information on the natural dispersal and the long distance dispersal of freshwater zooplankton communities is extremely limited and continues to be highly debated among researchers.

Natural Dispersal Mechanisms

Natural dispersal of zooplankton has been documented to occur through a number of vectors including: wind (Cáceres and Soluk 2002), rain (Maguire Jr. 1963), water flows (Michaels et al. 2001; Havel and Medley 2006), ingestion by water birds (Proctor 1964), transportation on the feet or feathers of waterfowl or waterbirds (Maguire Jr. 1963), and attachment to the feet or hairs of flying aquatic insects (Meutter, Stoks and De Meester 2008).

Spiny water flea dispersal into riverine habitats via downstream transport from infested lakes and reservoirs has been well documented in Minnesota. Biologists from Minnesota have recorded SWF "flushing" events from the Island Reservoir into the Cloquet River numerous times (Lindgren 2006). Drift nets set downstream of the reservoir indicate SWF can be flushed distances, upwards of 7-9 miles. Although flushing can transport adult SWF, dispersal does not necessarily result in a successful colonization.

The spiny water flea's reproductive ability is one of the most important aspects allowing for its dispersal and expansion into new locations. Like many zooplankton, SWF maintains two modes of reproduction. Asexual reproduction occurs most of the time producing clonal females; however, sexual reproduction produces the "seeds" that give rise to the next generation. These seeds take the form of resistant resting eggs. Spiny water flea resting eggs have a higher specific density than water (Yurista 1997) and sink to the lake bottom after they are released, indicating that natural dispersal of resting eggs by wind, rain or water flows is likely rare. However, natural dispersal of resting eggs by birds, insects and fish has a much higher probability of occurrence. Resting eggs of SWF can survive passage through the digestive tract of fish in viable condition, allowing them to disperse via interconnected aquatic ecosystems (Jarnagin et al. 2000).

Human-Induced Dispersal Mechanisms

Human-mediated vectors are generally considered the principal mechanism responsible for rapid dispersal of SWF in the United States. Recreational activities involving fishing or boating activities (bait buckets, live wells, fishing lines, anchor lines, and bilge water) present the most likely avenues for SWF to be transferred from one waterbody to the next (MacIsaac et al. 2004). Boating activity is extremely vulnerable to "hitch-hiking" by unwanted aquatic species, because the structure and design of a typical boat contains numerous surfaces, nooks, and crannies. These areas are not apparent to the average recreational boater, and often go unchecked for hitchhiking organisms. This is especially true of the SWF because its resting eggs may remain viable for over one year. Consequently, resting egg transfer is often overlooked, and likely represents one of the greatest human mediated dispersal mechanisms for SWF from infested to non-infested lakes.

If SWF should become established in the Hudson River, recreational boating on the river may increase the risk of SWF dispersal into Lake Champlain via "hitchhiking" and movement through the Champlain Canal during lockage from the Hudson River to Lake Champlain. The potential for accidental transfer via boating increases during times when Great Sacandaga Lake is discharging water that may contain SWF (i.e. May-September) and when boating activity is high.

Predators

Spiny water flea represents an interesting link in the aquatic food web when compared to other native planktonic species. Their size and long barbed caudal spine helps protect it from predation. However, it is slow moving, less transparent and possesses a prominent eye spot, which makes it susceptible to fish predators. Predation of the SWF has not been observed or documented by larger macroinvertebrates or waterfowl.

Spiny water flea is easily captured by numerous species of fish; however, gape-limited fish have a great deal of trouble ingesting the SWF (Barnhisel and Harvey 1995 and Branstrator 2005). Experimental observations indicate gape-limited fish spend nearly 10% more time trying to consume SWF as compared to other typical planktonic prey items, which ultimately leads fish to avoid SWF as a food resource (Barnhisel and Harvey 1995 and Strecker 2007). Other studies have also shown that spine consumption can physically pierce the stomachs of some fish (Compton and Kerfoot 2004) and one study indicates that SWF spines are indigestible, provide no nutritional value and may reduce growth by occupying space in the stomach (Stetter et al. 2005).

Non gape-limited fish, both juvenile and adult, can consume SWF without experiencing trouble related to ingestion. Examination of stomach contents has revealed that adult yellow perch, walleye, salmon and largemouth bass can consume considerable quantities of SWF (Barnhisel and Harvey 1995). Additionally, it has provided a strong source of prey for alewife, herrings, two perch species, shiners, walleye, chub and other fish throughout the Great Lakes (Burr and Klarer 1991; Hartman et al. 1992; Mills et al 1992). Furthermore, SWF bearing mature resting eggs were consumed selectively over those without eggs or immature eggs (Jarnagin et al. 2000). Some research indicates that SWF may even be considered a key prey resource (Hatton 2008), or may even become the preferred food source of larger fish species (Sikes 2002) in lakes with established populations. SWF likely has approximate dietary contributions similar to native prey items (Hatton 2008), and actually maintains a higher protein content than most native zooplankton due to its larger size (Barnhisel and Harvey 1995). Predation of the SWF has been well studied since its invasion into North America; however, the potential effect of this species on natural food webs still remains unclear.

Food and Feeding

The SWF is a uniquely adapted predatory planktivore that shows preference for large bodied zooplankton, typically greater that 2 mm (Berg 1992), especially species of the genus *Daphnia* **(Figure IV-5)**. The SWF is generally considered a voracious predator (Burkhardt and Lehman 1994; Schultz and Yurista 1999) capable of consuming prey as large as their own body. SWFs possess four pairs of prehensile legs used to grasp prey and employs stout mandibles that shred prey before consuming the body contents (Monakov 1972). Noningested fragments of prey resources released during feeding are typically unrecognizable (Berg 1992). One SWF may consume up to 20 prey organisms in a day and at times may exceed total zooplankton production (Dumitru et al. 2001). Although SWF seems to prefer cladoceran prey, it will also consume other abundant zooplankton species (Strecker 2007). The organisms eaten by SWF are also the preferred food of native plankton and fishes, leading to direct competition for food with native species (Berg 1992). Furthermore, since SWF can exert strong predatory pressure, there can be a resultant change in the food web.

Figure IV-5. Stage I SWF Chasing a Native *Daphnia spp*.
Source: Pecore et al. 2009

Ecological and Physiological Overview

Environmental Tolerances

Environmental tolerances of the SWF have been well studied and documented since its invasion into the United States and Canada. Research plays a significant role in developing an understanding of the regulating features and helps drive future management activities that limit the spread. Geographical distribution can also provide insight into a species' environmental tolerance (i.e. broad geographical ranges are likely to experience a wider range of conditions and have broad environmental tolerance) (Bonier, Wingfield, and Martin 2007). Based on research and the current distribution of the SWF, it appears that the SWF has developed strategies to tolerate a wide range of environmental situations. The SWF demonstrates plasticity in its physiology allowing it to rapidly adapt to environmental extremes.

Effects of Temperature

Water temperature plays a significant role in the ecology of SWF in North America. Seasonal water temperature fluctuations cue the activation of multiple phases in the seasonal life cycle of the SWF and directly impact seasonal population dynamics (i.e. growth, survival, and reproduction). The impact of temperature on the survival of SWF has been well researched. Yurista (1999) determined the upper lethal limit to be 74°F (23°C), Berg (1992) suggests sensitivity at 25°C (77°F), and Grigorovich et al. (1998) indicates a thermal tolerance range between 4°C to 30°C for optimal growth. These data are relative to observations made during numerous field studies (Garton et al. 1990).

Many lakes can only achieve lethal water temperatures within the surface layers, allowing SWF to escape through vertical migration to greater depths that provide a thermal refuge (Berg 1992). Similar to native planktonic species such a *Leptodora*, North American populations of SWF have shown the ability to acclimate to warmer temperatures relative to local conditions (De Stasio and Beyer 2009). Recent experimental data on exposure time and temperatures (De Stasio and Beyer 2009) indicates a wide range of variability. **Figure IV-6** presents graphical results of thermal tolerance experiments for temperatures ranging from 90-130 °F. With increasing time of exposure, an increasing percentage of SWF did not survive. After a 5 minute exposure to 110 °F, mortality was near 100 percent, while no individuals survived immersion at 120 or 130 °F.

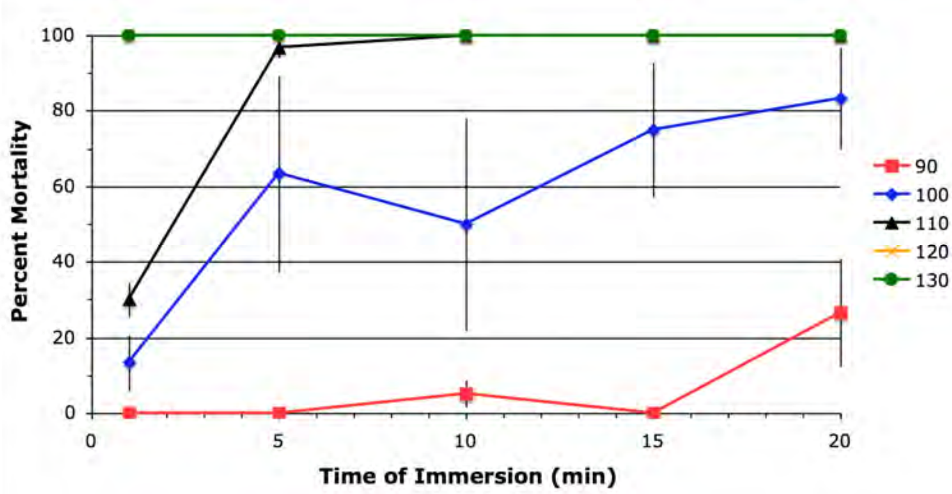


Figure IV-6. Spiny Water Flea Thermal Tolerance (Mean ± I SD)
Source: De Stasio and Beyer 2009

Respiration and Metabolism

Spiny water flea oxygen (O_2) consumption rates have not been well documented within the published literature; however, limited research has indicated respiration rates similar to those reported for native planktonic species (Lampert 1984; Krylov 1988). Yurista (1999) measured respiration rates for SWF individuals and found they can range from > 1 μg O_2 /h^{-1} for neonates to < 7 μg O_2 /h^{-1} for larger Stage III females. Stage III adults respire at a rate equal to approximately 14.4% of their total body weight per day, while Stage I and Stage II organisms respire at 28.4 % and 20.8%, respectively (Yurista and Schulz 1995). SWF maintain higher respiration rates per unit body size, making them less efficient at energy utilization; however, in times of oxygen stress, large bodied adult SWF would maintain a competitive advantage because of their reduced respiratory demand (Yurista and Schulz 1995).

Responses to Hypoxia/Anoxia

Spiny water fleas have developed a unique life history strategy that allows them to persist under conditions of low oxygen or hypoxia. For example, resting eggs sink to the lake bottom and become "dormant" until favorable conditions return. During this period of dormancy, resting eggs must cope with an environment that contains little to no oxygen. Andrew and Herzig (1974) found that resting eggs are capable of surviving for periods of approximately 280 days on their energy stores. Adult SWFs have also shown the ability to survive under low oxygen, and can tolerate oxygen concentrations as low as 2.4 mg/l (Grigorovich et al. 1998). Because SWF migrate to deeper areas within the hypoliminion, they are likely subject to variable oxygen concentrations on a daily basis and likely have an adapted metabolic process that copes with the changes in oxygen availability.

Salinity Tolerance

SWF has developed the ability to survive in oligohaline or low salt environments (Sikes 2002). This adaptation has helped this species traverse the saltwater barrier that lies between its native and introduced ranges. Oceanic or euhaline waters, often maintain a salinity range from 30 to 35 ppt, while estuaries (euhaline waters) mix with freshwater inputs delivered by streams and rivers forming brackish conditions with salinity ranging from 0.5 to 29 ppt (Nybakken 2003). SWF have evolved to tolerate mildly brackish conditions for extended periods of time. Grigorovich et al. (1998) indicates that SWF can withstand salinities as high as 8.0 ppt but prefers a much lower range (0.04 to 0.4 ppt). Furthermore, resting eggs can also maintain a high degree of viability after an exposure to high saline water (Bailey et al. 2005).

Resistance to Freezing and Desiccation

As described above, the SWF has developed a unique ability to withstand extended periods of unfavorable environmental conditions, including freezing. As a mechanism to survive during the winter, SWF has evolved to include a dormant stage in its life history. Dormancy takes the form of sexually produced resting eggs that are generated at the end of the growing season when environmental conditions begin to degrade. Resting eggs are released from the female and settle into the lake sediment until water temperatures rise above 4 °C. The eggs are protected by a thick cuticle and can persist in the environment for approximately 1 year, but do not represent a long-live egg bank (Strecker 2007). Recent research on resting egg desiccation and hatching indicates that SWF resting eggs may not remain viable after 12 to 24 hours of desiccation (Taube 2009). This is a critical life history component in stopping the spread of SWF via overland transport. Because SWF resting eggs may be susceptible to drying out, they may not be able to overwinter within the Glenn Falls Feeder Canal during the winter when the canal is drained.

pH Tolerance

The pH of water is a direct measure of the hydrogen ion concentration and indicates the degree of acidity or alkalinity in a lake environment. pH plays an important role in structuring an aquatic community and helps determine the availability of nutrients. Grigorovich et al. (1998) reported that SWF can tolerate waters with a pH that ranges from 4.0 to 8.0; however, SWF prefers more circumneutral conditions. Recent observational data collected by Strecker (2007) indicates that lakes impacted from acidification, are rapidly being invaded by SWF. Their ability to spread into lakes recovering from acidification is another indication of their phenotypic plasticity.

Effect of Water Velocity

Water velocity appears to be a significant regulating factor in the use of riverine environments by SWF. Flowing aquatic ecosystems such as rives and streams typically maintain planktonic populations that are dominated by smaller bodied species such as rotifers and do not typically produce the abundance of large clodoceran prey preferred by the SWF (Thorp et al., 1994). Water currents within these environments do not favor organisms that are poor swimmers such as SWF. However, SWF has been collected and determined to be established in more than 20 rivers within Minnesota (USGS 2009). Downstream transport from an infested lake is the likely cause of these riverine population establishments. Their presence provides compelling evidence to indicate that North American River systems can be colonized by SWF.

Effects of Sheer Stress and Turbulence

Hydraulic shear stress and turbulence are interdependent hydrologic phenomena that are also important factors in shaping zooplankton community density and population diversity. Elevated levels of shear stress and turbulence occur in a variety of natural aquatic environments; however, potentially damaging levels are often associated with man made features such as hydroelectric dams. Spiny water flea prefers a natural environment that maintains low levels of both turbulence and sheer stress. Given this preference, it is likely high levels of turbulence and sheer stress values, like those of a hydroelectric plant tailrace, would result in the mortality of SWF individuals; however, resting eggs may still remain viable (Personnel communication Kim Schulz, SUNY, Syracuse, 2010).

Impacts of Spiny Water Flea

The introduction and subsequent expansion of the SWF into North America has altered aquatic ecosystems. The spread of the SWF has the potential to create devastating economic effects, and significantly degrade the natural ecology of a particular system. Negative biotic impacts of SWF invasion have been well documented.

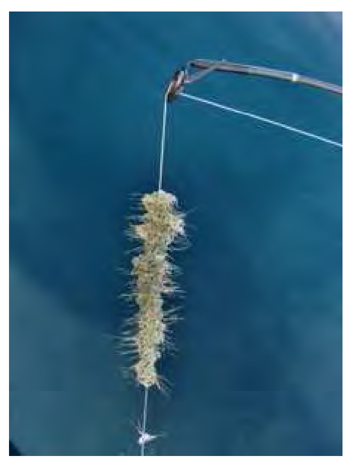


Figure IV-7. **Biofouling**
Source: Jeff Gunderson, Minnesota Sea Grant

Impacts on Water Users

Biofouling of recreational and commercial fishing line is one of the greatest abiotic impacts of SWF invasions and represents a serious economic problem. The long tail spines of the SWF are a nuisance to anglers because they tend to accumulate and significantly disrupt angling efforts (**Figure IV-7**). During peak abundances, fishing may be impossible because so many

SWF become attached to the line that anglers cannot reel in their lines. Loss of fishermen can lead to the dramatic reduction in the income for many fishing related businesses.

In addition to fishing line, SWF can also biofoul other commercial and recreational fishing gear including: nets, waders, lures, anchors, ropes, and motors, making anglers the perfect vehicle for SWF dispersal. Biofouling of both recreational and commercial fishing gear represents a significant risk pathway for the potential spread into new lakes. Draining infested livewell water from one water body into another waterway or a launch ramp may result in the release of nuisance species.

Biotic Effects

European and North American freshwater ecosystems have experienced profound changes as a direct and indirect result of the invasion of SWF. The following paragraphs summarize some of the observed ecological responses to the presence of SWF. Although this represents a comprehensive review of available literature, many biotic effects are yet to be realized as the presence of the SWF in New York is relatively recent.

Zooplankton

Nuisance predatory cladocerans, including the SWF are disruptive to native aquatic foodweb dynamics (Peacor et al. 2009). Because SWF occupies a mid-level trophic position, they can affect species located both above and below it on the food chain (Lehman and Branstrator 1995; Sikes 2002) through a combination of direct and indirect effects. Direct impacts to zooplankton populations include density effects and are usually more easily recognized. Evidence of its ability to modify species assemblages, and cause local extinction of those species is documented by the collapse of *Daphnia retrocurva* and *D. pulicaria* in areas of the Great lakes (Lehman 1987; Lehman 1991; Lehman and Cáceres 1993; Schulz and Yurista 1999). In Lake Michigan it preys on the largest zooplankton individuals unlike normal crustacean predators (Schulz and Yurista 1999) and at peak density can exceed internal plankton production rates. Morphological defenses (large crests, helmets, spines, and mucrones) of native cladocerans and rotifers evolved to protect them from native predators such as *Leptadora*; however, SWF is not deterred by these defense mechanisms. Ultimately, direct effects of SWF can lead to local extirpation of historic zooplankton species and can greatly reduce zooplankton biodiversity (Sikes 2002). Boudreau and Yan (2003) found a 30% decrease in biodiversity in Canadian Boral Shield lakes invaded by the SWF.

Indirect modifications are often less readily observed; however, these non-lethal or trait mediated effects can also exert strong affects on zooplankton populations (Pangle et al. 2007). In some instances, SWF predation on one species plays an important indirect role in freeing other species from competition or predation allowing for a historically repressed species to experience proliferation and increased abundance (Schulz and Yurista 1999). Recent experiments have demonstrated indirect effects of SWF including the ability to induce changes in *Daphnia* diel vertical distribution and habitat use, and reduce activity rates (Peacor et al. 2009). Field surveys seem to confirm experimental studies, documenting that *Daphnia* respond to SWF presence by migrating to lower, colder, waters during the day. Furthermore, indirect effects can lead to a reduction in growth rates and population density, and can shift species into habitats that make them more vulnerable to predation by fishes (Pangle et al. 2007).

Fish

The impacts of SWF on fishes has been hotly debated since its invasion; however, results clearly demonstrate that fishes are impacted by the presence of SWF. SWF can impact various life stages in fish populations in many complex ways through both direct and indirect interactions within the food web. Impacts are felt at multiple levels within the food chain and directly result in increased competition for limited food resources. Fish species that historically preyed upon *Daphnia sp*. have been forced to shift their diets (Branstrator and Lehman 1996; Bur and Klarer 1991; Coulas, MacIssac and Dunlop 1998; Jarnagin, Swan, and Kerfoot 2000; Mills et al. 1992; and Sikes 2002). In addition, SWF often replace native species as the main prey resources; however, their food resource quality has been debated. Smaller gape-limited fishes, including larval and young of the year, have trouble ingesting SWF because of the unusually long tail spine. This can lead to selective aversion or total avoidance (Berg 1992; and Barnhisel and Harvey 1995). Parker et al. (2001) determined that the retention of spines in juvenile smelt stomachs lead to overestimation of importance of the SWF as a food item. Furthermore, Stetter et al. (2005) indicated that indigestible spines of SWF provide no nutritional value to fish, reduce growth by occupying space in the stomach, and reduce the realized daily ration for rainbow smelt. Indirect effects on prey resources also lead to diversion of energy away from the early life history stages of fishes and minimize the recruitment potential of fishes (Peacor et al. 2009).

Complex food web interactions make it difficult to detect the effects of indirect impacts; however, it is important to view SWF invasion from a variety of perspectives in order to fully understand the breadth of environmental impact to fish populations (Peacor et al. 2009).

Benthic Invertebrates

The invasion of SWF has been documented to shift energy transfers within the pelagic food web of many lakes; however, benthic food webs found within the littoral zones of lakes often remain unaffected. Benthic invertebrate communities and littoral zone food webs are somewhat decoupled from the pelagic communities (Bertolo et al. 2005), thus SWF does not appear to directly impact benthic macroinvertebrates. However, piscivorous fish serve as integrators of pelagic and littoral food webs thus indirect impacts to predatory fish may result in increased macroinvertebrate production. Literature on this subject is limited and lacking the full breadth of study needed to fully understand how benthic and pelagic food web interactions are affected by SWF invasion.

Macrophytes and Algae

The excessive growth of submergent macrophytes is considered one of the greatest management concerns, and is a threat to the recreational use of lakes (Wedepohl et al. 1990). The excessive growth of submergent macrophytes is not likely to occur in lakes invaded by SWF because many are not light limited and are low in nutrient content. In turbid, light-limited environments, the presence of SWF may benefit macrophyte growth. An increase in algal production through the reduction of invertebrates feeding on these primary resources is also possible if basil nutrients are readily available. Increased light transmission into deeper portion of the lakes may also enhance the risk of increased primary production at deeper zones as well.

Likelihood of Potential Spread

Attributes of an organism's life history are critical in determining whether a population will spread and become established. Key life history elements that limit the ability of SWF to spread from Great Sacandaga Lake include: 1) preference of non-flowing lake habitats, 2) non-persistent resting eggs, 3) non-buoyant resting eggs, 4) relatively short generation time, and 5) susceptibility to fish predation.

In order for SWF to disperse between preferred habitats (Great Sacandaga Lake to Lake Champlain), it must navigate and survive a journey of over 50 miles of non-preferred riverine habitat before entering the south end of Lake Champlain (**Table IV-2**). To complicate the journey, the SWF must also endure numerous altered flow regimes including the EJ West Hydropower Facility. Natural dispersal of SWF resting eggs is also unlikely because the eggs sink upon their release and only remain viable for approximately one year. Resting eggs consumed by fish can remain viable; however, the likelihood of spread by fish is considered low because there is no fish passage structure at the EJ West Hydropower Facility, but the possibility still remains as some fish may survive passage through the power generation facility. Due to these factors, the likelihood of in-water passage of SWF from Great Sacandaga Lake to Lake Champlain is considered extremely low because of the long dispersal distance between the two preferred habitat environments (**Figure III-5**), the extreme turbulence at the EJ West hydropower facility, and the lack of a fish passage structure at the EJ West hydropower facility.

Table IV-2. Distance from Great Sacandaga Lake to Lake Champlain

Lotic Waterbodies	Approximate Distance (miles)
Sacandaga River	6.34
Hudson River	21.11
Glen Falls Feeder Canal	8.42
Champlain Canal	22.58
Total Distance	58.45

Many of the documented invasions into inland waters can be attributed to the overland movement of small boats that can be towed overland on trailers (MacIsaac et al. 2004). Thus, every time a boat is transported overland after use in an invaded waterway, there is the possibility that it will transfer an invasive species to an uninvaded waterway. Transient boaters that visit multiple waterways within a boating season present an elevated risk for transfer of invasive organisms. Furthermore, fishermen present an even greater risk of transporting organisms among waterways due to their propensity to use multiple lakes within one year. The use of specialized gear that holds or transports water such as live wells, bait buckets, and coolers also increases the risk of transporting organisms from infested systems. Since the most likely pathway for the SWF to have entered Great Sacandaga Lake was via transfer by man, it is also the most likely method for transfer to Lake Champlain. As such, construction of an engineered barrier may have minimal effect on the ultimate transfer or may merely delay it by a few years.

V. REVIEW OF POTENTIAL CONTROL METHODS

There are various options to limit the spread of the spiny water flea (SWF) from Great Sacandaga Lake to Lake Champlain via the Glens Falls Feeder Canal (Feeder Canal) and the Champlain Canal. This section summarizes general management alternatives and a number of technological control methods that have been documented for similar species in scientific journals, government and state reports, and manufacturer websites, although additional research that pertains specifically to the SWF would be beneficial. The primary methods for SWF control are preventing migration and inducing mortality. Potential management alternatives to accomplish these methods include prevention through education and public outreach, detection and monitoring, developing a rapid response plan, and implementing control methods. Since some management alternatives for ANS are already in place and have been discussed in other reports, the main focus of this section will be a detailed description of potential control methods that may be effective for limiting SWF spread. Although prevention of other ANS was not a focus of this report, many of the control methods discussed would also be effective in preventing spread of additional ANS.

Management Alternatives

There are various management alternatives that can aid in reducing the risk of SWF dispersal. This study discusses informing the public, knowing when and where SWF becomes established, being prepared, and implementing a tangible control method. A review of the management alternatives included in **Table V-1** is provided in the following paragraphs.

Table V-1. Summary of Potential Management Alternatives

Type of Management Alternative	Implementation and/or Maintenance Issues
Prevention through Education and Public Outreach	It is important to educate the public and recreational users about the impacts of SWF and guidelines that can be followed to aid in prevention of spreading.
Detection and Monitoring	Proper equipment and training must be provided for appropriate personnel to facilitate early detection and regular monitoring procedures.
Development of Rapid Response Plan	A coordinated rapid response plan should be developed that can aid management personnel in the event of detection in the Feeder Canal.
Implementation of Control Methods	Specific physical, chemical, or physiological methods can be implemented to control the spread of SWF.

Prevention through Education and Public Outreach

It is important to promote public awareness and understanding of SWF and their potential impacts to the ecological and economic health of lakes and rivers in the northeast region.

Outreach programs that promote commercial and recreational practices to prevent the spread of SWF are also important. These practices include the proper disposal of live bait, inspection of any boats or other equipment that is placed in infested waters, and proper cleaning procedures for equipment.

Figure V-1. Stop Aquatic Invaders Graphic
Source: www.protectyourwaters.net

The ANS Task Force public awareness campaign in an effort to control recreational spread of aquatic nuisance species has initiated the program entitled "Stop Aquatic Hitchhikers" on a national level. This program encourages recreational users to not only identify ANS present in their surroundings, but also follow a short list of guidelines every time they leave a lake, stream or coastal area. **Figure V-1** gives a short description of these guidelines.

At a local level, the Lake Champlain Basin Program (LCBP) has been proactive about controlling aquatic nuisance species. **Figure V-2** shows the extent of the Lake Champlain Basin. The fish, wildlife, and other living resources of the Lake Champlain Basin have already been negatively impacted by the introduction of many nonnative aquatic nuisance species. LCBP has developed two editions of a comprehensive management plan entitled *Opportunities for Action*: *An Evolving Plan for the Future of the Lake Champlain Basin*, which included a comprehensive action strategy to protect ecologically valuable habitats and to control the spread of nuisance species. The plan is expected to be updated every five years to make sure ongoing and emerging issues are addressed (LCBP 2003).

Figure V-2. The Lake Champlain Basin
Source: Northern Cartographic

Furthermore, an Aquatic Nuisance Species Management Plan for the Lake Champlain Basin approved by New York, Vermont and the National Aquatic Nuisance Species Task Force was accepted in 2000 and updated in 2005 (LCBP 2008). Implementation of this management plan is in progress throughout the Basin and results are being carefully monitored. Successful implementation of these plans is achieved by developing many joint partnerships among natural resource agencies, citizens, and other lake and watershed stakeholders. The LCBP has already sponsored a variety of projects to educate and involve the public and gather information about lake issues. The LCBP has also provided funding for education, planning, demonstration, research, and monitoring projects. These efforts are a perfect example of prevention through public education and outreach.

Detection and Monitoring

Early detection and monitoring efforts are critical to the discovery of new introductions of SWF and in accurately tracking the spread of existing invasions. Detection of this nonindigenous aquatic species is critical. Monitoring can be utilized to determine the specifications for developing control methods, such as frequency and urgency of necessary treatments. Efforts related to early detection and monitoring may include such activities as identifying at-risk sites; routinely monitoring certain areas; prevention and containment efforts; surveillance, detection and reporting activities including data collection and management; the collection, identification and storage of voucher specimens; and training volunteers and professionals in detection, identification and removal techniques.

Monitoring and survey programs within and adjacent to the Lake Champlain Basin are currently in place to document the occurrence and distribution of ANS populations. Specifically, the 2005 Lake Champlain Basin ANS Management Plan outlines several strategies for early detection, monitoring and research and lists several of the on-going monitoring programs in the region. Select programs/ actions that may relate to SWF monitoring in the target area are outlined below.

LC Long-Term Monitoring Program – Zooplankton- Continue to note the occurrences of nonindigenous aquatic species while analyzing zooplankton samples taken regularly at 12 stations throughout Lake Champlain as part of the *Lake Champlain Long-term Water Quality and Biological Monitoring Project*, a cooperative Vermont/New York effort coordinated through the LCBP.

NY CSLAP Monitoring Program- Continue to track new occurrences of ANS or changes in existing ANS populations in lakes within the New York portion of the Basin as part of New York’s Citizens Lake Assessment Program.

Additional Monitoring Programs- Utilize, develop, or expand other existing ANS monitoring programs or develop new monitoring programs, as appropriate, including citizen-based ANS watcher programs.

Maintain List of ANS in the Basin- Compile information from ANS monitoring and survey programs to maintain a list of aquatic nuisance species and their distributions both within the

Basin and those with the potential to enter it in coordination with other local and regional ANS panels.

Development of Rapid Response Plan

The following two actions from the 2005 Lake Champlain Basin ANS Management Plan outline the LCBP strategy to *Develop and Implement a Rapid Response Protocol for Addressing New Populations of ANS throughout the Lake Champlain Basin*.

Develop Rapid Response Protocol- In coordination with state, regional, and national rapid response plan development processes, develop a Lake Champlain Basin Rapid Response Protocol for addressing new introductions of ANS populations. Hire support staff to work with ANS subcommittee to develop protocol and pursue grant proposals and other funding sources.

Employ Rapid Response Team- Form and utilize ANS Rapid Response Teams to detect new ANS populations and to implement emergency control activities to eliminate new populations or to prevent populations from reaching nuisance levels. Hire support staff to work with ANS subcommittee to coordinate activities of rapid response teams.

In May 2009, the LCBP finalized a Rapid Response Action Plan for Aquatic Invasive Species. The Plan is intended to ensure and facilitate the availability of appropriate protocols, trained personnel, equipment, permits, and other resources to contain and potentially eradicate newly detected nonnative aquatic invasive plant, animal, and pathogen introductions as they are reported or discovered in the basin. The purpose of this plan is to have a process in place to react to a new invasion, or to the spread of an invasive species already in the basin. Of the species covered by this action plan, there are some that would almost certainly trigger the rapid response action plan with minimal or no preliminary discussion. These are species that have not as yet been recorded in one or more of the jurisdictions and have been shown to be, or have potential to be, highly invasive in other systems and have had environmental, economic or human health impacts. The SWF is one of these species.

The 2009 Work Group Report on Bi-national Aquatic Invasive Species Rapid-Response Policy Framework is also a useful reference since Lake Champlain is located in the U.S. and Canada. It emphasizes the importance of having a rapid response plan in place and recommends a policy framework. The framework lays the foundation for consistent and cooperative policies in the U.S. and Canada. Resulting policies will enable agencies to take charge and develop the detailed plans necessary for a unified response to an AIS incident occurring in shared waters.

Implementation of Control Methods

Technological control methods may include physical, chemical, or physiological measures to limit the spread of the SWF or induce mortality. These methods can be utilized to control SWF via limitation or eradication, but should be evaluated closely in order to determine a control method that will cause the least harm and environmental impact. A review of technological control methods is presented below.

Technological Control Methods

As outlined above, technological control methods discussed herein include physical, chemical and physiological measures. Most of the physical control methods are utilized to prevent all SWF life stages from spreading through the Feeder Canal via a physical barrier. Chemical and physiological control methods are utilized to induce mortality by chemical addition or other manipulation of water properties and are generally dependent on dose and contact time. Each of these technological control methods and specific alternatives are described in detail below.

Table V-2 summarizes each of the control methods that are discussed in this section. The table includes categories such as control techniques, estimated efficiencies, environmental impacts, range of probable cost, and recreational/historical impact, as the Feeder Canal is a historical structure utilized for recreational purposes. Estimated chemical dosing and filtration pore sizes are based on inactivation or removal of the resting egg. For clarity, the doses, efficiencies, and contact times that apply to the resting egg have been included in the appendix, which has a more detailed sizing sheet for each control method considered.

Assumptions

Facility**-** A key variable affecting selection of an appropriate control method is the large flow transferred through the Feeder Canal. The average flow rate is 250 cfs (162 MGD, 112,000 gpm), with a maximum flow of 500 cfs (325 MGD, 224,000 gpm). Any control method must be capable of treating the entire maximum flow at all times. For control methods to be most successful, the entire flow should be treated continuously. Furthermore, literature and personal communication suggest that 80 to 90 µm filtration units would be sufficient; however, there are indications that filter screen sizes in the range of 50 to 100 µm would be necessary. Differences may be a result of different life stage sizes with the neonate being the smallest. Based on a review of SWF biology, it appears that the most likely life stages of SWF to spread via in-water transfer are pelagic life stages and not resting eggs. These conditions result in large treatment facilities and increased construction costs. Fortunately, control methods would not be required during November through April when the Canal is drained.

Efficiency- It is important to note that some of the available information regarding mortality via chemical and physiological control methods is only cited for the fishhook water flea or zebra mussels. The fishhook water flea is smaller than the SWF but has very similar biological characteristics, including a resting egg life stage (MN DNR 2005). Zebra mussel veligers are also smaller than the SWF and are likely more susceptible to chemical and physiological control methods than SWF neonates. Doses and contact times necessary to affect SWF cannot be confirmed without further investigation (Watten 2010). Furthermore, it is possible that methods effective for zebra mussels may not have the same effect on SWF.

Cost- The cost opinions included in Table V-2 are believed to be good faith approximations of probable costs. These costs are based on preliminary vendor pricing information and/or costs from similar installations. It should be noted that actual costs could vary after a preliminary design level or more detailed implementation strategy is developed for a particular alternative. In particular, building sizes are estimated based on available information. Pre-treatment requirement for some control methods may be adjusted based on further testing of the River water. Land acquisition is identified where appropriate, but is not included in the probable cost estimate. Additional analysis of selected alternatives beyond the evaluation in this report will be required in order to more accurately narrow these cost ranges.

Table V-2. Methods for Control of Spiny Water Flea

Control Method	Description	Purpose	Estimated Efficiency	Facility Requirements	Operational Requirements	Operational Costs	Impact on Recreation	Potential Issues	Range of Probable Cost *
Physical	Media Filtration	Limit Spread	>95%	Large treatment building to house filters. Support facility for backwash storage/disposal.	Backwash filter, disposal of backwash waste		High, all flow directed through filtration unit	Very large area required for gravity filters, could require pumping and pre-treatment	>$100M
	Granular Rubber	Limit Spread	70-90%	Large treatment building to house filters. Support facility for backwash storage/disposal.	Backwash filter, disposal of backwash waste		High, all flow directed through filtration unit	Very large area required for gravity filters, could require pumping and pre-treatment	$50-100M
	Microfilter	Limit Spread	>95%	Large treatment building to house filter units and pretreatment. Support facility for pumps, compressed air, CIP neutralization/disposal, chemical deliver and storage	CIP of filters, disposal of CIP waste and backflush waste	Energy for pumping, cleaning chemicals, pre-treatment costs if needed	High, all flow pumped through filtration unit	Large filter building required. Pumping required	>$100M
	Permeable Barrier	Limit Spread	>95%	Requires 1+ acre of material. Boat launch requried. Small facility for compressed air for pressurized air cleaning system.	Clean filter, check integrity, seasonal placement and removal	Fabric inspection/repair, fabric replacement, compressor operation	Minimal if located in the Hudson River	Rips/clogging	<$10M
	Irrigation Filter	Limit Spread	>95%	Requires approximatly forty (40) 80um units, including backups. Flush water supply and treatment/disposal of wasted water.	Flush water treatment		High, all flow pumped through filtration unit	Pumping required	>$100M
	Rotating Drum Filter/ Disc Filter	Limit Spread	>95%	Inline or in new parallel channel. Screening storage/disposal facility.	Cleaning/check integrity, manage screenings		High, all flow diverted through rotating drum filters in channel	Large number of units required	$20-50M
Chemical	Chlorine Injection with dechlorination	Mortality	Dependent on Dose and Contact Time, 50-100%	Chemical storage, off-loading and metering for chlorination and dechlorination. Storage volume for retention time unless channel is used.	System maintainance, very frequent chemical deliveries	Chlorine and dechlorination agent (ie sodium bisulfite)	High, portion of channel may be a holding tank to provide retention time	High dose requirement, providing retention time, dechlorination potentially required	>$100M ($50-100M for lower dose)
	Ozone Injection	Mortality	Unknown; possibly 50-100% depending on dose and contact time	Chemical production and metering. Storage volume for retention time.	Maintain ozone generation system and diffusers	Ozone generation	High, portion of channel will be toxic, potential for holding tank to provide retention time	Dose dependent on water temperature	>$100M
Physiological	CO_2 Injection	Mortality	Dependent on Contact Time, 50-90%	Chemical production and metering facility. Storage volume for retention time.	Maintain CO_2 generation system and diffusers	CO_2 generation	High, portion of channel will be a holding tank to provide retention time	Dose dependent on water temp, not 100% effective on eggs	$25-50M
	Heating/Boiling	Mortality	Dependent on Contact Time and Temperature, 50-95%	Large boiler house. Storage volume for heating and cooling. Support facility for fuel storage.	Boiler/burner maintenance and cleaning, fuel system inspections	Energy	High, portion of channel will be a holding tank to provide retention time	Energy required to heat water	$50-100M
	UV Radiation	Mortality	Unknown; possibly 50-100% depending on dose and contact time	CIP solution and backwash storage. UV inline or in new parallel channel. CIP chemical storage and unloading. Waste storage/disposal.	Bulb Replacement, cleaning units	Energy	High, all flow will be diverted through UV	Lens fouling	>$100M

* Does not include land acquisition

CIP- Clean in place

Physical

The physical control methods reviewed below are physical barriers that would prevent the spread of SWF into the Feeder Canal. Filtration methods are generally effective for prevention, assuming that the pore opening is sized to exclude the undesired species. Literature review of the SWF egg size suggests a filter with 50 μm (Surprenant 2009) to 100 μm (personal communication with Kimberly Schulz, SUNY, Syracuse) pore size would exclude all eggs.

All physical options require site considerations for constructability. A large footprint may be required for some filters to provide sufficient surface area for the high flow rate. In addition, process buildings with backwash treatment, control rooms, etc. may be required. In high pressure loss systems, pumping of the entire flow will require a large pump station, with electrical service. Most of these filtration options require solids handling of the backwash or wasted water, which could require a permit for discharge.

Permeable Barrier

A permeable geotextile barrier with a small mesh size (e.g., 100 μm) would extend from the River bottom to the surface of the water (**Figure V-3**). Gunderboom, Inc. manufactures filter fabrics that are utilized as exclusion systems in marine settings, typically at cooling water intakes for power plants. Although not currently used specifically for the SWF, the Gunderboom technology may be efficient in controlling the spread of the SWF eggs since it excludes material above the pore size of the fabric. Debris drawn into the geotextile fabric, such as sediment and other floating organisms, can be removed using the AirBurst system. High pressure air, supplied by air compressors in a support building, is released at the bottom of the panels. These air bursts shake the fabric and release any material trapped within the fabric. Control systems can be setup to monitor load on the panels, which signals for an air burst.

There are several disadvantages; one being, given the small pore size, other aquatic species could be captured along with potential for biofouling. Another disadvantage is that the fabric must be removed at the end of the Canal's navigational season, prior to winter, and reinstalled in the spring before the Canal is reopened. The fabric could require replacement. The fabric may also require replacement if damaged by large woody debris during high flow events. Larger debris in the water column may need to be removed by a structure or diversion upstream of the barrier to prevent rips or tears. The fabric is generally resistant to rips or tears as long as it is not placed in a rigid frame.

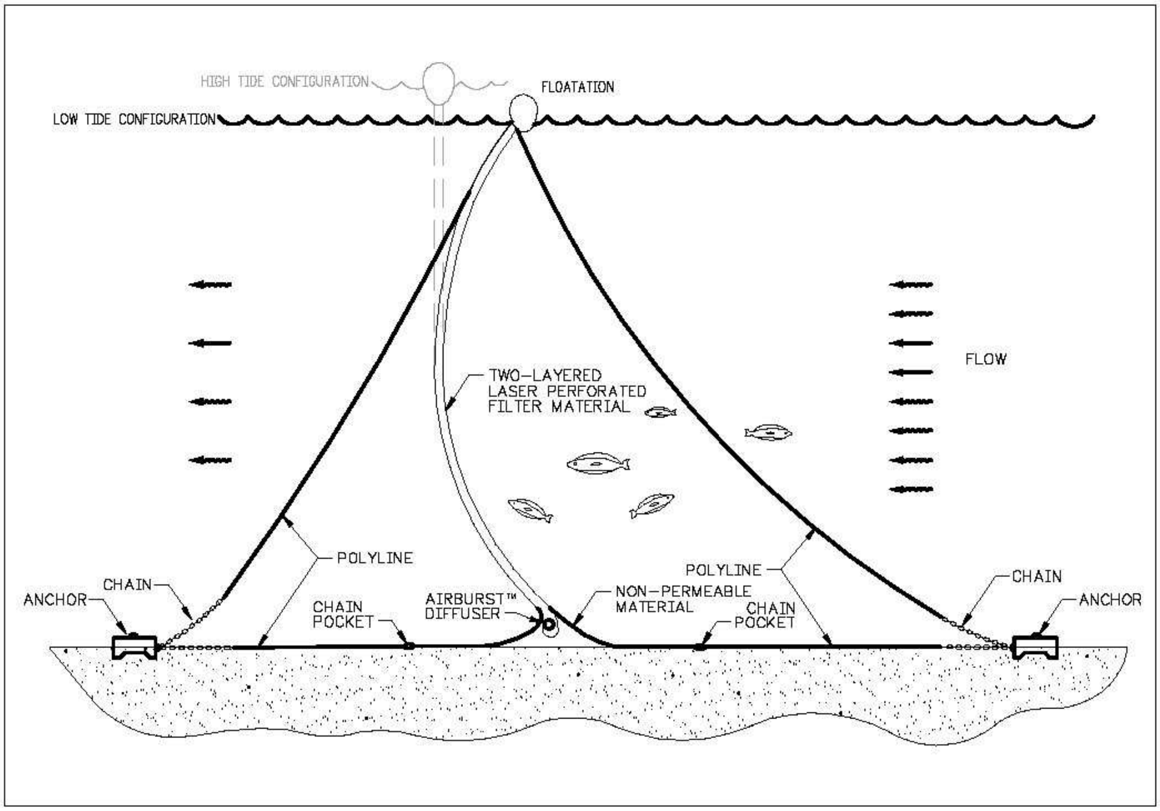


Figure V-3. **Conceptual View of Permeable Barrier**
Courtesy of Gunderboom, Inc.

Mechanical Filtration

Multiple filtration options were reviewed, including microfilters, sand/multi-media filters, crumb rubber filters, irrigation filters, and drum filters. All of these filters work by excluding material above a certain size from passing through. All of these filtration options will generate a solids stream, either from backwash or wasting. The high-solids waste stream must be stored, treated, and discharged, which could require a discharge permit. Some of these options require high feed pressure, which will require a large pump station. Filtration systems are difficult for a high flow open water system such as the Canal, as a large surface area will be required. A key advantage is that, compared to the chemical methods, the filtration options have a lower environmental impact on the Canal.

Microfiltration

Microfilters are high pressure filtration units with pore sizes typically in the range of 1 μm. One advantage of microfilters is that the small pore size will likely provide 100% capture of the SWF egg. However, pre-treatment of the River water would be required to prevent rapid flux loss due to clogging of the microfilters. In addition, backflush waste would be generated, requiring treatment and/or disposal. Chemical cleaning of the microfilter membranes is required periodically. Chemical storage would be needed, plus collection, neutralization, and disposal of the chemical cleaning waste.

Sand/Multi-media/Crumb Rubber Filters

This grouping of filters are units that utilize media, whether sand, anthracite/sand, crumb rubber, etc., to filter the water. Application rates for these media units can range based on feed properties, however sand filters are typically fed at 4 gpm/ft^2 and the crumb rubber filters at 10 to 20 gpm/ft^2. Removal rate for the crumb filter is expected to be 70 to 90% (Tang et al. 2009; Xie 2002). These loading rates result in large surface area filters; 56,400 ft^2 is required for the sand filter and 22,500 ft^2 for the crumb rubber filter. This would require a number of filter cells stretched over a large space. One option would be to use the Canal bed as a filter. A key disadvantage of this is the significant work that would be required in the historical Canal, plus there would be a large impact on recreation. Alternately, the Canal water could be diverted out of the Canal to a new filter facility, with the filtered water discharged back into the Canal.

Pumping would possibly be required if a location for gravity flow can not be located in or adjacent to the channel. The need for pumping would add significant capital and operational costs to this option. A significant water supply would be required for backwashing of the filters. Testing would be required to determine the actual loading rate for each filter type and frequency of backwash.

Irrigation/Pressure Strainer Filtration

Self-cleaning irrigation/strainer filters are pressure vessels with wire screens used to treat large flows of water (**Figure V-4**). Amiad is a leading manufacturer of this type of filter. Their largest unit is the Mega EBS, which can be provided with screen size ranging from 10 μm to 500 μm. For an 80 μm filter, the maximum flow rate is 6,000 gpm, requiring 38 units at the maximum flow rate. An additional 20% increase in units is recommended for maintenance or downtime, resulting in a requirement for 46 units. A 4-unit manifold of the Mega EBS filters measures 15 ft by 33 ft. Based on this sizing, the process building is anticipated to be approximately 9,000 ft^2. In addition, the pressure requirement for these units requires pumping of the River water.

Figure V-4. Pressure Strainer Array

Drum/Disc Filters

Drum and disc filters are micro-screens which capture particles on a screen fabric while allowing water to pass through. They have a rotating frame that houses filter panels manufactured with polyester or stainless steel filter cloth. They can be operated with little head loss on gravity flow designed with few moving parts to ensure a long life with low operating/maintenance costs. The filtering process can be efficient and reliable due to the overall design and operation; however, multiple units would be required for this application as the largest units are capable of processing up to 10,000 gpm or more. To process the estimated 224,000 gpm (500 cfs) it would require a minimum of 23 units. Another three to five units should be included for redundancy and backup for maintenance. Square footage for installation would require approximately 2,500 to 3,500 ft^2. Drum/disc filters can be manufactured with screen sizes below 100 µm and thus can be estimated above 95% effective. With this porosity, it is likely pre-treatment will be needed to remove large particles and reduce the solids load to the drum filters. Units could potentially be installed in the current channel or a new parallel channel depending on number and size. Using the canal for treatment could be challenging due to historical and recreational impacts.

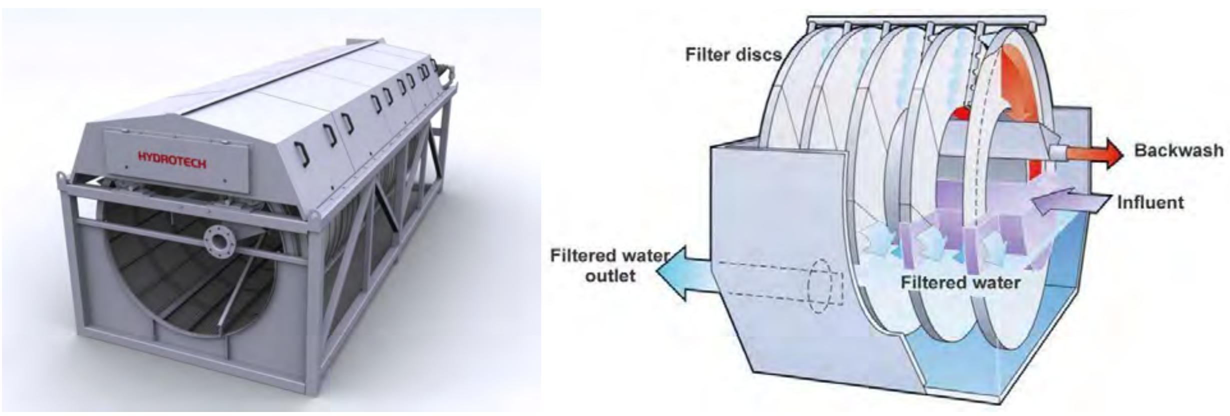


Figure V-5. Examples of Drum and Disc Filters

Similar to other filter options, pumping may be required if a location for gravity flow can not be located in or adjacent to the channel. The need for pumping would add significant capital and operational costs to this option. A significant water supply would be required for backwashing of the filters. Testing would be required to determine the actual loading rate and frequency of backwash. Solids storage, hauling and possibly permitting would also be necessary.

Chemical

Spiny water flea control methods in this grouping create environmental or toxic impacts that are caused by chemical additions. Chemical treatments are very feasible for public facilities that can control the amount of chemical discharge, but they are less practical for open water systems such as the Feeder Canal. In addition, the recreational uses in and around the Feeder Canal impact the feasibility of chemical treatments. If there is a concern of environmental impacts or harm to other aquatic life, non-chemical treatments would be recommended as many of the chemical control methods are toxic to aquatic life. Due to the high toxicity of chemical additions in general, it is important to survey all chemicals to determine which one will be the most effective and least harmful for each particular water system.

The chemical treatment options require considerable site considerations for constructability. Large facilities for chemical storage and/or generation are required, with associated chemical delivery pads and containment. These facilities need to be located for easy truck access for chemical deliveries. Modifications to the Feeder Canal, or addition of a retention area, will be required for some options to provide the required contact time with the chemical. Chemical bulk storage is dependent on the dosing requirement, but will likely be large given the high maximum flow rate of the Feeder Canal. If the flow must be diverted to the treatment system through a pumping station, significant electrical service will also be required. Furthermore, since these treatment options involve introduction of chemicals into raw water, a discharge permit may be required.

Chlorine

Chlorination is the most common method for treatment of undesired species, such as viruses and zebra mussel infestation, in public facility waters; however, it is not commonly used in treatment of open waters. Use of chlorination in open waters has a high environmental impact (i.e., generation of trihalomethanes, which are a chlorination byproduct). In addition, chlorination is highly toxic, not only to the SWF, but to other aquatic species. Another disadvantage to chlorination is that the residual chlorine must be removed prior to discharge via dechlorination.

Chlorination is typically performed with either liquid sodium hypochlorite or chlorine gas. Use of chlorine gas is generally being phased out due to safety concerns, therefore hypochlorite would be recommended. Dechlorination is typically performed with sodium bisulfate or sodium thiosulfate, with the dose dependent on the chlorine dosing but typically 1.4 mg/L of bisulfite per mg/L of residual chlorine or 4:1 thiosulfate to chlorine application. A higher chlorine dose will therefore result in a higher residual chlorine concentration to be dechlorinated.

Chlorination could be performed either along the length of the Canal or can be performed in a separate holding area. If the Canal is used for contact time, the required contact will be provided as the chlorinated water travels through the Feeder Canal. This option would require continuous chlorination along the length of the Canal to maintain the required concentration or overdosing at the point of application. If a holding area is required to provide the contact time, the flow could either be diverted from the Canal to a storage area or the Canal could be built up to provide the required contact time.

The need for dechlorination could be minimized by discharging the high chlorine liquid into the Canal and using the natural consumption of the residual chlorine in the channel after discharge. This would require a permit and would have a high environmental impact.

Effectiveness of chlorination is dependent on both the chlorine dose and contact time provided. Review of literature shows 10% household bleach is effective in killing 100% of fishhook waterflea resting eggs with a 1 hr contact time (MacNeill et al. 2004). Note this dosing is equivalent to a chlorine concentration of approximately 5,000 mg/L, based on a typical household bleach concentration of 5%. A chlorine dose of 5,000 mg/L is excessive, and would make chlorination unappealing due to the chemical usage and storage requirements to provide such a high dose to a 500 cfs flow (13,000,000 gpd 12.5% hypochlorite, with a 65,000,000 MG tank to provide 5 days storage). In addition, sodium bisulfite usage and storage would be high.

A more reasonable chemical dosing would be on the order of 5 mg/L; however no data for effectiveness in this dosing range was available. Note that MacNeill et al. (2004) indicate the mortality rate for the fishhook water flea resting egg decreases to 89% at a contact time of 10 minutes in 10% household bleach, suggesting that the resting egg is quite resilient to chlorination and a lower chlorination dose may require a lengthy contact time. Although this dose is more feasible economically, effectiveness at this dose must be investigated if this option is pursued.

Ozone

Ozone is another oxidant that is frequently used to control unwanted aquatic species, such as zebra mussels. No data for ozone mortality of SWF was obtained; therefore, this option was not reviewed in detail. For preliminary sizing and costing, a concentration of 0.5 mg/L for five hours was used based on previous experience with zebra mussels. This option should not be pursued without performing tests to determine effectiveness of ozone on SWF. One benefit of ozone compared to chlorination is that ozone dissipates naturally, and no chemical addition is required to remove excess or residual ozone. Disadvantages of ozone include its sometimes explosive nature and rapid dissipation in surface waters. Dissipation will decrease the amount of exposure time per dosing and essentially lead to higher costs to sustain the treatment.

Physiological

Physiological control methods result in mortality of SWF by directly affecting their environment. In the cases below, environmental extremes are created by addition of CO_2 to create an anoxic condition, the application of heat to create an intolerable temperature, or exposure of UV radiation. Similar to chemical treatments, these methods are less practical for open water systems such as the Feeder Canal and may have environmental impacts to other aquatic life. Furthermore, the use of carbon dioxide and UV radiation to induce mortality has not been specifically documented for the SWF.

All physiological options require site considerations for constructability. A large footprint may be required to provide sufficient surface area for the high flow rate. In addition, process buildings for pre-treatment and backwash related to UV treatment, generation of CO_2, control rooms, etc. may be required. Modifications to the Feeder Canal or addition of a retention area will be required for some options to provide the required contact/exposure time. If the flow must be diverted to the treatment system through a pumping station, significant electrical service will also be required. Furthermore, since these treatment options involve manipulation of water properties, a discharge permit may be required. A discharge permit may also be necessary for the backwash from pre-treatment filtration prior to UV exposure.

Carbon Dioxide/Nitrogen

A discussion with Dr. Barnaby Watten (USGS) occurred to investigate the potential for carbon dioxide injection to the water column as it has proven to be effective in the control of other aquatic nuisance species within the ballast water of ships. A conceptual view of this application is provided in **Figure V-6**. The use of this technology in the treatment of ballast water resulted in lowered pH, anoxia and gas bubble disease. This technology may be effective in controlling all life stages of SWF except for the resting egg. However, dosage rate and exposure time for mortality to occur within an open system, such as the Feeder Canal, requires further research. An alternate gas, such as nitrogen, may be used to cause anoxic conditions; however pH will not be affected. An advantage for using carbon dioxide is that it can be readily generated at the site for the treatment process. In addition to need for additional research on the dosage rate and exposure time to achieve mortality, work needs to be completed to determine the retention time of the carbon dioxide once in the Canal and what levels it would be at as the water flows to the Champlain Canal.

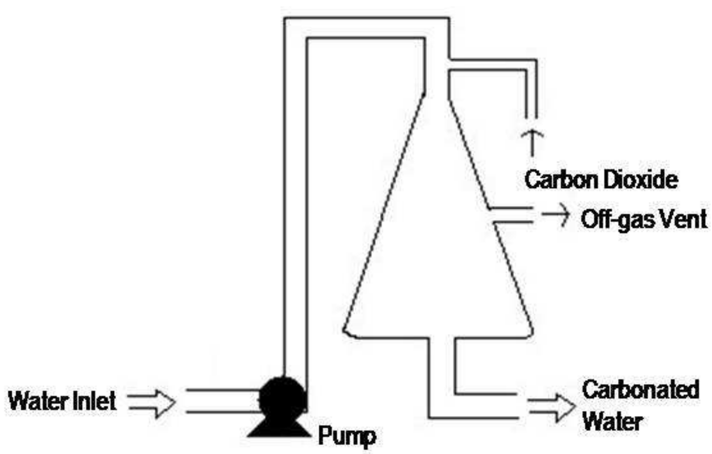


Figure V-6. Conceptual View of CO_2 Injection Vessel

MacNeill et al. (2004) reviewed the mortality of nitrogen gas on fishhook water flea resting eggs. Introduction to an anoxic environment is not expected to result in a high mortality rate as exposure to nitrogen gas for two and three days resulted in mortality rates of 55% and 65%, respectively (MacNeill et al. 2004). Similar rates would be expected for carbon dioxide; however, this would have to be confirmed. The high contact time would result in a large storage volume for nitrogen and substantial generation equipment for the production and injection of carbon dioxide.

Heating

Spiny water flea thermal tolerance was discussed in Section IV. In summary, laboratory tests showed 100% mortality after one minute at 120ºF and almost 100% after five minutes at 110ºF for adults (DeStasio and Beyer 2009). Although this study did not specifically test SWF egg mortality, it was speculated that only two percent of the egg pouches observed appeared to survive a five minute exposure to 110ºF. MacNeill et al. (2004) reviewed the effect of heating on the fishhook water flea resting egg. Exposure to boiling water (212ºF) is 95% effective after 10 sec. At the lower temperature of 40° C (<110ºF), effectiveness decreases to 50% after 10 sec. Bringing the Canal to the boiling point would be energy intensive and would be toxic to most other aquatic species. Although the contact time is low, leading to a fairly small retention time, a large heating unit would be required to heat to boiling quickly. If retention time could be increased, the temperature could be decreased and the size of a heating unit would be smaller. In addition, a chamber to hold the water for cooling would be required. Permitting could also be required due to the discharge temperature.

UV Radiation

UV radiation is typically an effective method for controlling zebra mussels in all life stages, although effectiveness in controlling SWF has not been documented. For other species, effectiveness of UV is dependent on the dose and contact time. Turbid water or water with high suspended solids will decrease UV intensity and require a longer contact time. Even if effective on SWF eggs, UV radiation is similar to chemical addition and will have a toxic affect on other aquatic species. In addition, UV implementation for this flow rate would have a high capital cost. Use of UV radiation to kill SWF must be investigated prior to pursuing this option.

VI. ANALYSIS AND RECOMMENDATIONS

This section provides an in-depth analysis of the control methods presented in **Section V** and ranks the options based on efficiency, cost, environmental impact, etc. A numerical rating system was created to rank the various options. Five categories were used in the ranking matrix: expected efficiency; facility/land requirements, including constructability; operational requirements; impact on environment and recreation; and opinion of probable cost. It should be emphasized that the preferred option will need further study to confirm assumptions made at this conceptual stage.

Analysis of Potential Control Methods

Table VI-1 contains the matrix rankings and results. Each of the five categories was scored on a scale of 1 to 5, with a lower value representing a lower impact or more preferred option. The categories utilized to evaluate control methods are outlined below. Combinations of options were not considered, given the high cost and land requirements for most of the individual control methods which, if combined with another treatment option would result in even greater cost and land requirements.

Effectiveness in Preventing Migration (Mortality or Limit Spread)

Where possible, theoretical effectiveness is used based on field and laboratory studies. Additionally, any efficiency claims made by product manufacturers were considered. In some cases, efficiency is speculated based on similar treatment options or similar species. Filtration options have the best efficiency rating, since small enough pore size will prevent passage of the resting eggs.

An objective rating for this category was prepared based on the expected range of efficiency. This category is weighted twice as high as the other categories in order to emphasize its importance in relation to all other categories.

Facility

This category ranks the space requirements for the treatment process and associated buildings, including whether it requires use of a portion of the Canal channel. Many of the options rank poorly here due to the large footprint for the filtration solutions or retention area to provide contact time for chemical treatment options.

Operational

This category ranking includes anticipated manhour requirements for operations and maintenance plus costs for chemical delivery, utility costs, and/or disposal of waste streams. This value is highest for chemical applications due to the recurring cost of the chemical and the large volume of chemical required for the high flow. In addition, UV and heating have high energy costs, as do any options with pumping.

Environmental/Recreational Impacts

Recreational Impacts & Public Perception - The probability that control methods would alter or impact activities such as swimming, fishing, boating, and subsequent public perception or willingness to accept the potential outcomes of the control methods are considered. Many of the filtration options fare poorly here, as all flow in the Canal must be bypassed through the treatment system.

Impacts to Non-Target Species – There are potential environmental impacts and toxicological impacts to other species (e.g., plants, benthic invertebrates, and fish). All treatment options will negatively impact any desired aquatic species as they will be removed along with the target species. However, many of the chemical and physiological options scored more poorly as they have the potential to affect a longer section of canal until fully neutralized.

Capital Costs

This study demonstrates the relative difference in capital costs between alternatives. Very broad ranges were given because the design criteria and site-specific information needed to fully define costs will require further development and study during the subsequent design phases. In addition, the opinion of probable cost does not include any costs for land acquisition associated with any specific control method. Operations and maintenance costs are reflected in Operations above.

Summary

Study Rating – The overall rating of each control method is a sum of the five categories, with effectiveness counting twice as much as the other categories. Therefore the best score would be 6, while the worst would be 30. This numerical value is meant to provide an *estimated* ranking for each treatment.

Table VI-1. Control Methods for Spiny Water Flea

Control Method	Description	Purpose	Expected Efficiency*	Efficiency Ranking	Facility Ranking	Operational Ranking	Environmental/ Recreational Ranking	Range of Probable Cost **	Cost Ranking	Study Ranking
Physical	Media Filtration	Limit Spread	>95%	1	5	4	5	>$100M	5	**21**
	Granular Rubber	Limit Spread	70-90%	3	5	4	5	$50-100M	4	**24**
	Microfilter	Limit Spread	>95%	1	5	5	5	>$100M	5	**22**
	Permeable Barrier	Limit Spread	>95%	1	2	2	1	<$10M	1	**8**
	Irrigation Filter	Limit Spread	>95%	1	4	3	5	>$100M	5	**19**
	Rotating Drum/ Disc Filter	Limit Spread	>95%	1	3	2	2	$20-50M	2	**11**
Chemical	5,000 mg/L Chlorine Injection with Retention Pond	Mortality	Dependent on Contact Time, 50-100%	3	4	5	5	>$100M	5	**25**
	5,000 mg/L Chlorine Injection using Channel for contact time	Mortality	Dependent on Contact Time, 50-100%	3	4	5	5	>$100M	5	**25**
	5 mg/L Chlorine Injection with Retention Pond	Mortality	Unknown; possibly 50-100% depending on contact time	5	2	3	4	$50-100M	5	**24**
	5 mg/L Chlorine Injection using Channel for contact time	Mortality	Unknown; possibly 50-100% depending on contact time	5	2	3	4	<$10M	1	**20**
	Ozone Injection	Mortality	Unknown; possibly 50-100% depending on contact time	3	5	3	5	>$100M	5	**24**
Physiological	CO_2 Injection	Mortality	Dependent on Contact Time, estimated 50-90%	3	3	3	2	$25-50M	2	**16**
	Heating/Boiling	Mortality	Dependent on Contact Time and Temperature, 50-95%	3	2	4	5	$50-100M	4	**21**
	UV Radiation	Mortality	Unknown; possibly 50-100% depending on contact time	5	3	2	5	>$100M	5	**25**

1- More desirable; 5- Less desirable

*Efficiencies listed for ozone and UV are reported for zebra mussels

** Does not include land acquisition

As described below, review of **Table VI-1** demonstrates that there are many advantages and disadvantages to each control method. The table, first and foremost, provides a list of control methods that is rated according to the *overall effectiveness* of the treatment at the specific site under consideration. Secondly, the table incorporates key factors, such as costs and environmental impacts that may be critical in determining which control method is most advantageous for this project. The study rating in the last column of the table is a numerical summation of the effectiveness and the other key factors that were considered when each alternative was evaluated.

Table VI-1 shows that many of the physical technologies have attractive characteristics, but they have low overall desirability due to cost, size of the treatment system, and other impacts. **Table VI-1** also shows that the chemical options generally are less desirable due to cost, environmental impact, and process size. Control methods with a study rating of 20 or over can be considered poor options for this project due to cost, poor effectiveness for mitigating spread, or implementation difficulties. The technologies that received the best ratings (8 and 16) are both physical treatment options. The control methods in these categories that received the best study ratings are the most effective, mainly due to high reported efficiencies and ease of application. Further analysis of each control method listed in the table is provided in the following discussion.

Physical

Physical barriers are generally more environmentally friendly and may require less permitting effort and expense; however, many of them are not feasible for large flows and open water due to the required low loading rates and potential need for pre-treatment. For treatment of the Canal water, most of the physical control methods are problematic in implementation and scale due to the high flow conditions. The constructability of mechanical filtration is reduced when treating such a large volume of water due to the surface area of filter required. Separately, a physical barrier could be implemented near the Canal inlet, which would prevent migration of the SWF into the Canal.

Overall, high filter surface area and process footprint, along with the associated capital costs, are the main disadvantages to many of the physical alternatives evaluated. The permeable barrier, however, is an exception in terms of a lower capital cost and relative ease of implementation, along with an expected high efficiency in capturing the SWF resting egg if the correct porosity is chosen.

Mechanical Filtration

Mechanical filtration options reviewed include drum screens, microfilters, sand/media filters, crumb rubber and irrigation filters. **Table VI-2** summarizes the review of the filters.

Table VI-2. Filtration Options for Prevention of Spiny Water Flea Migration

	Pore Size (µm)	Required Filter Area (sf)	Pre-treatment Required	Pumping Required
Microfilter	1 – 10	3,000	Yes	Yes
Sand/Multimedia Filter	NA	56,500	Possibly	Likely
Crumb Rubber	NA	22,500	Possibly	Likely
Drum Screen	60	7,500	No	Not Likely
Irrigation Filter	80	1,600	Not likely	Yes

Note that the required filter area presented in **TableVI-2** does not include excess capacity that would be required to provide redundancy when units are off-line for cleaning or repair. Reviewing **Table VI-2** shows some of the key disadvantages that result in poor rankings for the filtration options.

- The microfilter and irrigation filters require pumping, which will be expensive for the 500 cfs flow that is sometimes present in the Canal.

- The sand and crumb filters require very high filter surface areas, and may need pumping unless an area adjacent to the Canal can be located that can accommodate the filters and has sufficient head for flow via gravity. Alternately, the Canal bed could be converted to a filter bed. As an example, the 56,500 ft^2 sand filter would require a 0.7 mile long section of the Canal, assuming a 15 ft width, be converted to a filter bed. This portion of the canal would need sufficient head loss for the River water to percolate through the sand media into an underdrain collection system.

- The number of drum/disc screens and installation arrangement could be problematic, as the water will need to be diverted from the canal, through the filters and back to the canal. This could be accomplished immediately after the water enters the feeder canal if enough space is available to do the installation.

These filtration options typically generate backwash or other waste water that would require storage and/or treatment. Generation rate and properties would have to be determined through field or laboratory trials. Process water would be required for many options, for either backwashing or flushing of the filter units. For example, each irrigation filter unit generates 530 gal of wasted water per cleaning cycle. Frequency of the cleaning cycles would have to be determined, but at one cleaning per day per filter, 20,000 gpd of waste would be generated, requiring treatment and disposal.

Permeable Barrier

For this option, a permeable barrier, such as the filter fabric manufactured by Gunderboom, would be installed in the Hudson River upstream of the Canal. All flow would have to pass through the permeable barrier prior to entering the Canal. Using a design flow of 5 gpm/ft^2, based on previous experience, and assuming an average depth of 17.5 ft (USFWS indication that depth in the River in this area ranges from 15 to 20 ft), 2,600 linear ft of material would be required. The system would be installed with load cells to monitor sediment deposit on the filter fabric. High loading would trigger an air burst to shake material off the fabric. Because the fabric can be installed outside of the Canal, implementation is much simpler and the cost, therefore, much less. The environmental impact is low; however, there will be an impact on recreation since the structure will extend well upstream of the Feeder Dam. The Gunderboom installation can accommodate changing water level, as the float on the surface will rise and fall with water level. The surface area of the fabric dictates the potential flow through the membrane, as the gpm/ft^2 is based on the pore size of the fabric. At high flow in the River, the flow through the Gunderboom will not increase beyond the design flow of 500 cfs.

Capital and operational costs are fairly low for the fabric, although replacement of the fabric could be required. Replacement frequency would be based on River conditions. In addition, the fabric must be removed from the River prior to winter, which would coincide with the period when the Canal is closed for the season. The fabric must then be reinstalled in the spring prior to opening the Canal. Periodic inspection and repair of the fabric would be required due to the potential for tears. There is a potential for large debris to accumulate or cause tears in the fabric, although the fabric is resistant to tearing as long as it is not in a rigid frame. Accumulated debris would need to be removed periodically unless a structure or diversion to catch large debris is installed upstream of the permeable barrier. This issue may require further investigation to better determine the debris load in the river.

Chemical

Chemical treatments have some advantages over the other control methods because they tend to have high efficiencies and are relatively easy to implement and operate within open water systems. The key problem is providing sufficient retention time and, for chlorination, providing adequate chemical storage. In addition, the use of oxidizing chemicals such as ozone and chlorine in natural, open water systems is problematic due to toxicity and impacts to non-target organisms, potential occupational safety issues, and the regulatory permitting issues/restrictions. The chemical options are reviewed in more detail below.

Chlorine

As noted in **Section V**, a chlorine dose of 5,000 mg/L would be required based on available information relating to destruction of the egg stage of a similar organism. A more reasonable chlorine dose of 5 mg/L was also reviewed in the ranking matrix; however, this option would require testing to determine effectiveness as the resting eggs showed good resilience towards chlorine. **Table V-2** summarizes chemical usage and storage requirements for the chlorination option. Both hypochlorite and dechlorinating bi-sulfite chemical usage was considered. **Table V-2** shows that the 5,000 mg/L dosing required to achieve 100% mortality, as noted for fishhook waterfleas in MacNeill et al. (2004), requires an extremely high chemical usage with high annual chemical costs. Annual chemical costs are based on a 7-month operating period for the Canal during which chlorination would be required. The 7-month operating period is based on the Canal being drained in November and filled in April.

Table VI-3 below summarizes chemical usage and storage requirements for the chlorination option. Implementation costs for chlorination at the 5,000 mg/L dosing are excessive due to the storage tank size and required retention time. At the required 1 hr contact time for 100% mortality, 13.5 MG of storage/retention is required. This can be accomplished by either diverting the Canal into a contact tank or utilizing the Canal for chlorination. If a contact tank were utilized, the tank would have to be approximately 350 ft long x 350 ft wide x 15 ft deep, or almost 3 acres in surface area. In addition, the flow would need to be able to enter and exit by gravity. No site with this available space was observed for the contact tank. If the Canal were used for contact time, an almost 4 mile length of the channel would be required to chlorinate to the required dose.

Table VI-3. Chlorine Dosing Requirements at 500 cfs

	Chlorine Dose (mg/L)	
	5,000 mg/L	**5 mg/L**
Hypochlorite Usage (gpd)	13,000,000	13,000
5-day Hypochlorite Storage (gal)	65,000,000	65,000
Bisulfite Usage (gpd)	6,000,000	6,000
5-day Bisulfite Storage (gal)	30,000,000	30,000
Annual Chemical Cost ($/yr)	>$100M	$6M

Overall, the major disadvantages for chlorine include the chemical usage, associated annual cost for chemicals, and the sheer footprint of the required contact chamber. In addition, chlorine is toxic to most other organisms that will be present in the Canal. Chlorine can also generate trihalomethanes when in contact with organic matter.

Ozone

Compared to chlorine, ozone is advantageous due to its lower toxicity toward non-target species and quick dissipation. There would likely be high capital and operational costs associated with maintaining the proper ozone concentration to cause mortality of the SWF resting egg. A key disadvantage of ozone is that mortality of the SWF from ozone has not been demonstrated. Due to the unknown effectiveness and toxic effect of ozone on other aquatic species, the ranking for ozone is poor. Preliminary sizing was done using dosing and contact time required for zebra mussels; however, this dosing must be demonstrated in the field or laboratory. At this contact time, a 14 acre contact tank with a 15 ft depth, or 19 miles of the Canal channel would be required. Clearly, neither of these size requirements is feasible.

Physiological

Physiological control methods could have harmful ecological impacts due to the fact that the intent is to create an undesirable environment for the SWF. Other disadvantages include constructability, potential occupational safety issues, and regulatory permitting issues/restrictions. For instance, the treatment of the large continuous volume of water could impact overall effectiveness by limiting the exposure or contact time, or would impact constructability due to facility requirements.

Carbon Dioxide

In discussion with Dr. Barnaby Watten (USGS) the LD_{50} for SWF is not known. Further research will be required to determine dose and exposure time for mortality rate. The addition of carbon dioxide will most likely lead to mortality of SWF by creating a change in pH and an anoxic environment. It is assumed all life stages, except the resting egg, will be negatively impacted. Application/implementation will be the challenge, but once introduced to the water it will stay within the water column until agitation and dissolution of the carbon dioxide occurs. This could occur naturally as it degasses as it flows along within the canal, or it could be reclaimed with further technology. The application of carbon dioxide has the potential to impact all living organisms as it will affect pH and oxygen and, has been shown to create gas bubble disease within an organism, resulting in mortality.

It is proposed to apply side stream technology to introduce the carbon dioxide to the canal water column. Proper sizing and injection levels will have to be determined during design if this technology is selected.

Nitrogen

The addition of nitrogen has resulted in mortality of SWF, however, even after a two day holding time, the mortality rate was estimated to be only 55%, based on documented work with fishhook waterfleas and nitrogen gas (MacNeill et al. 2004). The required retention volume for two day storage would be 133 acres of storage tank, assuming a 15 ft depth. The ranking is poor due to the size of the contact time chamber and expected cost for carbon dioxide generation.

Heating

Effectiveness of heating is only demonstrated at boiling temperatures. Energy required to bring 500 cfs to the appropriate temperature is excessive, resulting in a poor rating. A large boiler facility with associated fuel storage would be required. Operating and maintenance impact would be large, between maintenance of the boilers and operating costs for fuel.

UV Radiation

UV radiation scores poorly in the ranking as effectiveness has not been proven on SWF. In addition, capital and energy costs are generally high with UV systems. The potential for turbid water or high TSS also impacts the effectiveness of UV. For instance, the treatment of the large continuous volume of water could impact overall effectiveness of UV radiation by limiting the exposure or contact time, or would impact constructability due to the large number of UV units required to provide adequate exposure.

Treatment Locations

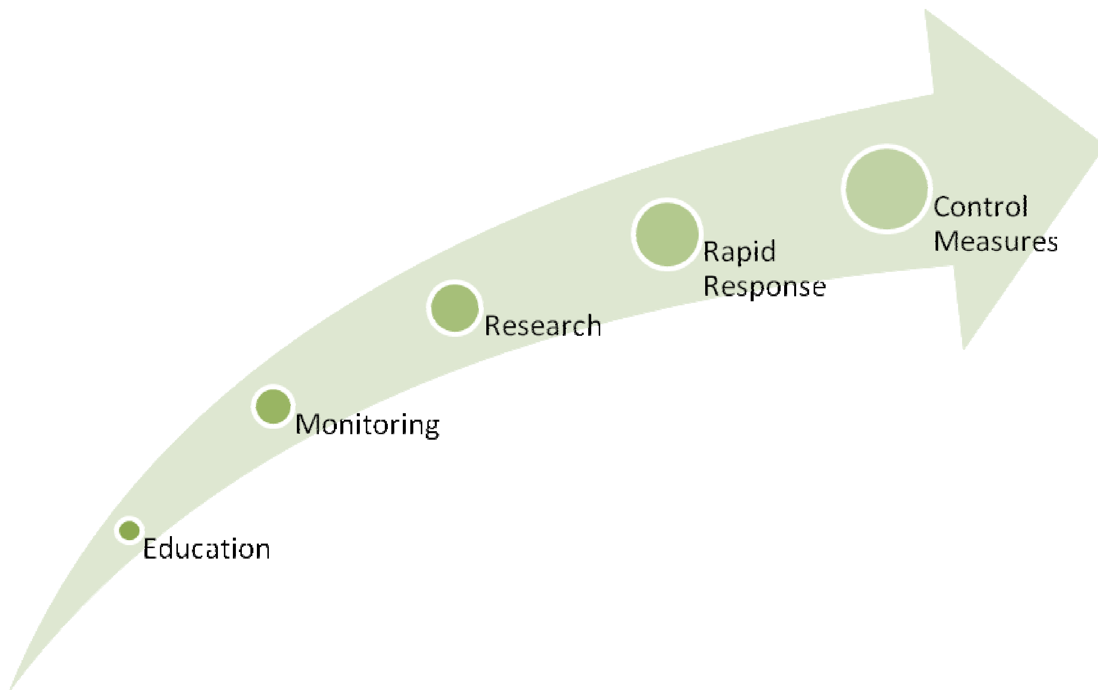
Limiting the downstream movement of SWF could occur either in the Feeder Canal or just upstream of the Feeder Canal inlet in the Hudson River. Diversion of flow out of the Feeder Canal into a new treatment facility is an option also; however, this would require acquisition of land adjacent to the Canal, most of which is developed. Construction in the Feeder Canal is complicated as it is a historic site, which would make it difficult, if not impossible, to obtain permission to install control methods. To minimize impact to the historical Feeder Canal, one option would be to capture the water prior to entering the Canal. The primary space available adjacent to the Feeder Canal inlet is parkland, which would make acquisition of land for a treatment facility difficult. Flows are even greater in the Champlain Canal than the Feeder Canal, which would increase sizing of any control method if treatment were attempted in the Champlain Canal.

Other Considerations

Section V briefly mentioned effectiveness and implementation issues for the control methods reviewed; however, the elements of design and construction have not been discussed. Some of the control methods require design and construction of a specialized system for the Feeder Canal. For instance, the permeable barrier mesh size and layout would be designed specifically for this application. It may also include further design development for protection from large objects, such as trees or logs that may be transported within the river water column. For control methods that may not require extensive construction, a design phase is still important in order to assess the site and provide specifications for proper treatment. Many of the options reviewed require significant design effort to adequately size the treatment process, identify an appropriate site, and minimize impact on the historical Canal.

Findings and Recommendations

Removal of the SWF once established will be difficult, costly and potentially impossible. Therefore, it is important to be proactive by focusing on prevention of SWF migration. As stated previously, one goal of this evaluation was to provide an analysis of the effectiveness of potential technologies in preventing or limiting the in-water migration of SWF from Great Sacandaga Lake to Lake Champlain. This can be accomplished with either physical methods that act as a migration barrier or chemical/ physiological methods that result in mortality of SWF. Although in-water control methods could be very effective in prevention of migration through the Feeder Canal, this does not guarantee that the SWF will not migrate into Lake Champlain via other means or vectors. Prevention of transport by other methods, such as in boats or fishing gear, may be the most likely method of transfer to Lake Champlain. Since SWF can be transported by many vectors, the recommended strategy for prevention of SWF spread to Lake Champlain includes five objectives: education, monitoring, research, rapid response and control measures, as outlined below. The actions discussed below will not only be instrumental in preventing SWF spread but may also prevent spread of other ANS to Lake Champlain.



Objective 1: Education

Continue and emphasize an educational campaign that informs the general public about SWF and the efforts that are needed to limit spread to Lake Champlain. According to the 2008 State of Lake Champlain report, the main pathways for introduction of ANS to Lake Champlain include unauthorized fish stocking, bait fish release, and passage through the canals. This stresses the importance of public education and outreach. Spread prevention, including public education, is an ongoing high priority in the Lake Champlain Basin in order to keep nuisance species such as the SWF out of the Basin (LCBP 2005). Specific programs that relate to the SWF should be emphasized and a cooperative outreach and education program should include participation from the NYS Canal Corporation, NYDEC, USFWS, and the LCBP at a minimum. The Lake Champlain Basin Program (LCBP) has produced the following documents that contain information regarding public outreach and education, and a list of entities involved in ANS management: *Opportunities for Action* (2003), *Lake Champlain Basin Aquatic Nuisance Species Management Plan* (2005), and *State of the Lake* (2008). These documents were briefly discussed in **Section V** and can be found at www.lcbp.org. Two strategies related to public outreach and education that are included in the ANS Management Plan are listed below. Actions proposed to implement these strategies are described in the Plan.

Strategy B1. Expand Lake Champlain Basin ANS Education & Outreach Programs

Strategy B2. Increase Opportunities for the Sharing of ANS Information throughout the Lake Champlain Basin and Beyond

Objective 2: Monitoring

Continue implementation of a comprehensive monitoring program to document occurrences of SWF in the pathway between Great Sacandaga Lake and the Champlain Canal. Detecting new invasions quickly and rapidly responding to them to contain the spread is more cost effective than managing or eradicating an established species (LCBP 2008). Furthermore, developing a comprehensive understanding of the presence and distribution of the SWF through early detection surveys and monitoring programs is a prerequisite for formulating effective strategies to limit the spread of SWF. New York and Vermont have volunteer monitoring programs to identify and report sightings of nuisance species, including the SWF. Furthermore, the LCBP Long Term Biological Monitoring Program expanded its monitoring in 2009 by sampling for SWF occurrences four times in the Feeder Canal and Champlain Canal. An increased monitoring effort including additional locations and increased sampling frequency should be considered. Specific locations and sampling frequency should be determined by the appropriate partnering agencies and organizations. These may include but are not limited to the NYS Canal Corporation, NYDEC, USFWS, and the LCBP.

Objective 3: Research

Conduct further research so that potential technologies to limit the in-water spread of SWF can be adequately evaluated. After an exhaustive literature review, it is apparent that further research targeting mortality of the SWF, adaptation to riverine environments, etc. is necessary. Future research will hopefully provide more information related to SWF mortality under various chemical and physiological conditions. While literature suggests specific mortality rates, dose and contact times for UV, ozone, CO_2, and chlorine injection in relation to fishhook water fleas and zebra mussels, there is no available literature for SWF. These unknowns make it difficult to properly determine the best available technology for limiting the spread of SWF. Furthermore, literature suggests that SWF will not establish in a riverine environment but occurrences have been documented in Minnesota. Additional research related to resting egg desiccation and freezing, and water flow tolerances would confirm opinions stated in this document.

Objective 4: Rapid Response

Develop a rapid response protocol specific to spread of SWF from Great Sacandaga Lake to Lake Champlain through the Glens Falls Feeder Canal and Champlain Canal. Given the hydrologic connection between Great Sacandaga Lake and Lake Champlain, there is a direct pathway for SWF spread. Although a rapid response protocol that applies to the Lake Champlain Basin has been developed, it may be beneficial to review the protocol and develop specific actions that would be necessary if SWF is detected below Great Sacandaga Lake. This would include establishing a critical control point(s) which triggers control actions. Such actions could only be considered if all involved agencies and organizations approved of this first line of defense against SWF spread. The intent of preventing SWF spread would have to be weighed against the recreational and commercial impacts and must be coordinated with all interested and effected parties and agencies.

Objective 5: Control Measures

This will involve measures to control two different types of transfer: human-mediated and in-water. As discussed previously, the likelihood that SWF will transfer to Lake Champlain as a result of human activities is greater than the probability of in-water transfer. Based on this conclusion, control measures to prevent the human-mediated spread of SWF are just as important, if not more important than preventing in-water transfer.

Implement control measures that limit the human-mediated spread of SWF to Lake Champlain. Public education and control measures to address human-mediated spread go hand in hand. If recreationists are unaware of the risks, they are likely unaware of prevention measures and will not implement simple actions to prevent an unintentional introduction of ANS, such as the SWF. Two examples of control measures that may prevent human-mediated introduction are listed below; however, additional options should be considered as well.

Installation of cleaning/disinfection stations at boat launches would provide boaters and fishermen a designated location and supplies to clean their boat, trailer, and any other associated gear that may have been in contact with infested waters. These cleaning stations could consist of steam cleaning or the use of disinfectants. Practical locations would include boat launches at both Great Sacandaga Lake and Lake Champlain, as well as any other water body that is known to have SWF. Waste from these stations would need to be treated prior to discharge.

In order to ensure boaters and fishermen are educated and implementing proper measures to clean and disinfect all equipment that may contain a hitch-hiking organism, site inspection may be necessary. For instance, the LCBP, in cooperation with partners, has initiated a steward program to provide education about aquatic invasive species spread prevention at boat launches. This program could be expanded to include launches in the pathway between Great Sacandaga Lake and Lake Champlain.

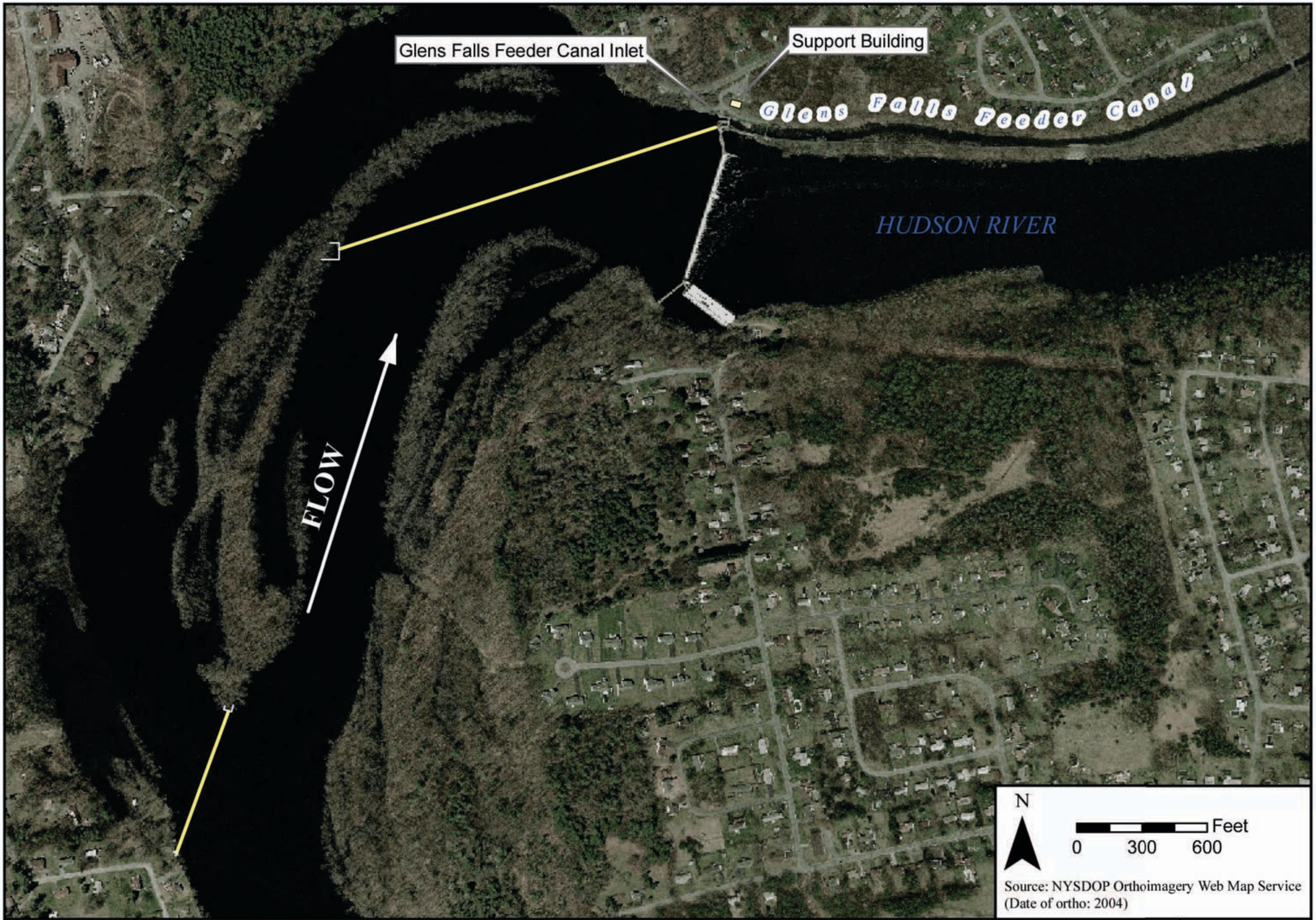
Install a physical barrier to limit the in-water spread of SWF through the Feeder Canal. The control methods presented in **Section V** were objectively analyzed based on environmental and scientific/engineering points of view. Evaluation criteria included expected effectiveness, economics, facility and operation aspects, and environmental and recreational impacts. Due to high costs and environmental/recreational impacts, chemical and physiological control methods were poorly rated. Most of the physical methods evaluated had a high efficiency but some would be very costly to implement. One major advantage of any physical barrier is that it will also prevent the in-water spread of other ANS to Lake Champlain.

Permeable Barrier

Overall, the Gunderboom technology appears to provide the best combination of a low cost, minimal environmental and recreational impact, and effectiveness at preventing migration. It is important to note that there are drawbacks associated with the permeable barrier that must be weighed against the cost of the system and potential for entry of SWF into Lake Champlain via alternative methods. While the permeable barrier is relatively easy to implement, compared to most of the other control methods evaluated, there are some drawbacks, primarily related to recreation and the potential for physical damage by large, waterborne debris which could compromise the effectiveness of the barrier. These disadvantages are minor and can be managed with additional engineering design.

Figure VI-1 below shows a proposed layout. In this layout, the fabric runs largely parallel to the shore line. The direction of flow in the River could help sweep debris off the fabric. There is still a potential for large debris to accumulate or cause tears in the fabric. Accumulated debris would need to be removed periodically unless a structure or diversion to catch large debris is installed upstream or in front of the permeable barrier. This issue may require further investigation to better determine the debris load in the river. Alternative locations were reviewed, however the River was deemed most suitable. Placing the Gunderboom in the Champlain Canal would leave no place for accumulated material to be discharged during an air burst. Other potential arrangements in the River could be reviewed during detailed design.

The presence of the two small islands upstream of the Feeder Dam results in a less than ideal installation; however, the installation is feasible. A support building will be required to house the compressors for the air bursts to clean the fabric and to store the fabric in the off-season. A possible location for this support building is shown on **Figure VI-1**. One potential issue with the permeable barrier is treatment of water downstream of the barrier after installation in the spring. This water could potentially contain SWF and would be utilized to fill the Canal for the new season. One potential method to minimize the impact would be to direct the initial water used to fill the Canal to the Hudson River, via the Champlain Canal.



HDR

Preliminary Gunderboom Layout

Figure VI-1

Rotating Drum or Disc Microscreen Filters

Another control method worth considering includes rotating membrane microscreen filters. The water flow could be diverted from the canal into another channel where the filters receive the water, filter it and then flows back into the canal. A diagram depicting a general layout of how this may look is included below (Figure VI-2). These microscreen filters would have a membrane opening of 80 – 90 µm to effectively remove all life stages of SWF, including eggs. Pretreatment of water with a coarser screen having larger openings will be required to prevent larger debris from entering the drum/disc filter. This may include the installation of self cleaning T-screens attached to the front of the Feeder Canal intake. The microscreens would require a powered backwash to remove the filtered materials and prevent the membrane from becoming clogged. Depending on permit requirements, these backwash materials could be re-introduced to the River. If this is not possible, a collection and treatment facility would be required that would result in periodic removal of collected solids for off-site disposal.

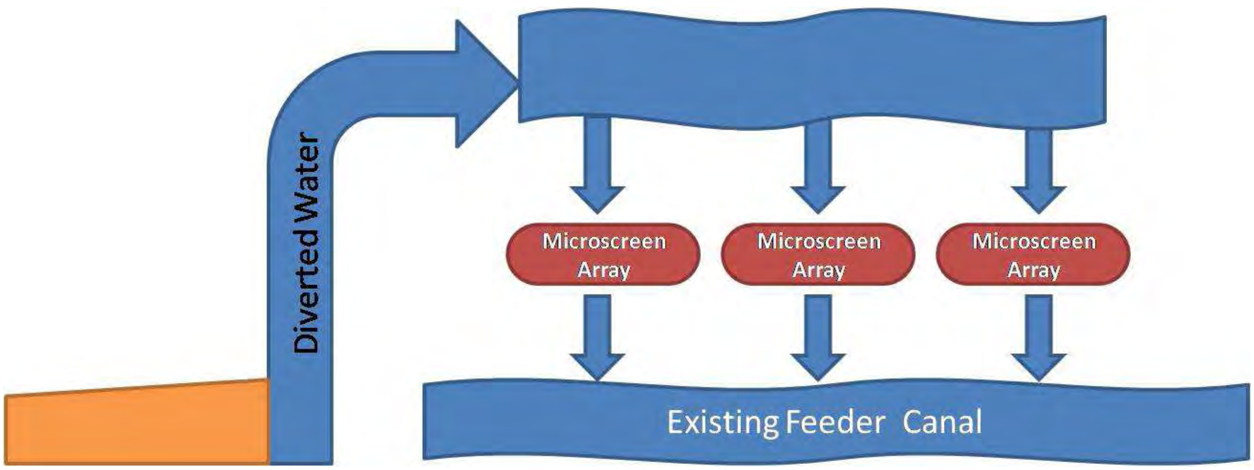


Figure VI-2. Potential Layout for Rotating Drum or Disc Microscreen Filters

Implementation

To adequately address the spread of SWF, all objectives will require implementation on varying timelines. It is evident that there is a correlation between the spread of SWF and human activities, i.e., commercial shipping and recreational boating. To this end, it is important that the public becomes cognizant of how they can affect further dispersal of the SWF. This is and should continue to be an on-going process. Monitoring is an integral part as it establishes a timeline of when the species occurs and how fast it disperses. This can help determine how fast control strategies need to be enacted. Similar to outreach and education, monitoring is and should continue to be an on-going process. Potential control strategies to limit the spread of SWF have been identified and will require prior budgetary support to implement in a timely manner. As the risk for in-water spread becomes more realized, it is recommended that appropriate funding be obtained to implement the planning, design, permitting, and ultimately the installation of a physical barrier as outlined above. In the meantime, control measures that prevent the human-mediated spread of SWF from infested waters should be the focus.

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APPENDIX A: Control Measure Calculations

1. Media (Sand) Filter

Comments:
1) Pumping may be requried, based on location and head loss
2) Backwash water required, plus collection/treatment/disposal for backwash water
3) Loading rate, and potential pre-treatment, would need to be confirmed for the River

Design loading rate=	4	gpm/ft2	10 state standards 4.1.2.2 rate of filtration for rapid gravity filters				
Flow in Feeder Canal							
Average	250	cfs	162.5	mgd	112,847	gpm	
Max	500	cfs	325	mgd	225,694	gpm	
filter sf required	56,424	ft2					
assumed average channel width	15	ft					
required length	3,762	ft					
	0.71	mi					
Pricing							
installed media filter cost	$1,500	$/sf	$1,000 to $2,000 per sf typical on HDR projects				
Media filter cost total	$85,000,000						
Contingency	50%	due to potential for lower loading or need for pre-treatment					
Total media filter cost	$127,500,000						

2. Crushed Rubber Filter

Comments:
1) Pumping may be required, based on location and head loss
2) Backwash water required, plus collection/treatment/disposal for backwash water
3) Loading rate, and potential pre-treatment, would need to be confirmed for the River

Review of Loading rate

	10	gpm/ft2	Xie, Y, USGS Water Resources Research Grant Proposal, Project 2002PA3B
low pressure application	49	m3/hr/m2	Tang, Z., Marine Environmental Research 61 (2006), 410-423
	20	gpm/ft2	
high pressure application	220	m3/hr/m2	
	90	gpm/ft2	

Design loading rate (low pressure) =	10	gpm/ft2
Design loading rate (high pressure) =	90	gpm/ft2

Flow in Feeder Canal

Average	250	cfs	162.5	mgd	112,847	gpm
Max	500	cfs	325	mgd	225,694	gpm

Pricing for low pressure

filter sf required	22,569	ft2	
installed media filter cost	$1,500	$/sf	$1,000 to $2,000 per sf typical on HDR projects
Media filter cost total	$34,000,000		
Contingency	50%	due to potential for lower loading or need for pre-treatment	
Total media filter cost	$51,000,000		

Pricing for high pressure

membrane sf required	2,508	ft2	
installed media filter cost	$1,500	$/sf	$1,000 to $2,000 per sf typical on HDR projects
Media filter cost total	$3,761,574		
pumping unit cost	$0.18	$/gpd	Lift station, RS means 2009 2nd Qtr, Union, Poughkeepsie, NY, 33.32.13.13-Cost works
pumping	$57,200,000		
Contingency	50%	due to potential for lower loading or need for pre-treatment	
Total media filter cost	$91,000,000		

3. Microfilter

Comments:
1) Typically 1 um
2) Would need to test/verify flux for actual River conditions
3) Pre-treatment likely required (coarse sand filter, etc)

Design flux =	75	gpm/ft2					
Flow in Feeder Canal							
Average	250	cfs	162.5	mgd	112,847	gpm	
Max	500	cfs	325	mgd	225,694	gpm	
membrane sf required	3,009	ft2					
Pricing							
installed MF cost	$1.75	$/gpd	$1.25 to $1.75 gpd typical on HDR projects (Roger Noack to Dedrick Damato)				
MF cost total	$570,000,000		includes pre-treatment				

4. Gunderboom filtration fabric

1) 50-100 um filter mesh
2) Actual throughput must be confirmed for mesh size and River characteristics

Review of loading rates:

4	gpm/ft2	ENSR, NYSDEC project 4-31814-00052
10	gpm/ft2	Southern Energy Delta LLC, Contra Costa Power Plant, Aquatic Filter Barrier Demonstation Project
5	gpm/ft2	HDR Experience

Design throughput =	5.0	gpm/ft2				
Flow in Feeder Canal						
Average	250	cfs	162.5	mgd	112,847	gpm
Max	500	cfs	325	mgd	225,694	gpm
sf of fabric =	45,139	ft2				
assumed depth =	17.5	ft	(based on depth at feeder dam gate per site meeting 12-2-09)			
length of Gunderboom =	2,579	ft				
Pricing						
Gunderboom unit cost	$27	$/sf	quote from Gunderboom for 3000 ft, 20 ft wide			
			includes supports, air clean, etc			
Gunderboom cost	$1,600,000					
Building Size						
total area	1,500	sf				
building unit cost	$300	$/sf	(includes building and footings, electrical, HVAC, etc)			
cost for building	$450,000					
Cost Determination						
compressor and piping install	$800,000					
sub-total	$2,850,000					
mod/demob, OH, profit, etc	25%	(mob/demob, overhead, profit, insurance, bonds, etc)				
contractor costs	$712,500					
subtotal cost	$3,562,500					
contingency	50%					
probable cost =	$6,000,000					

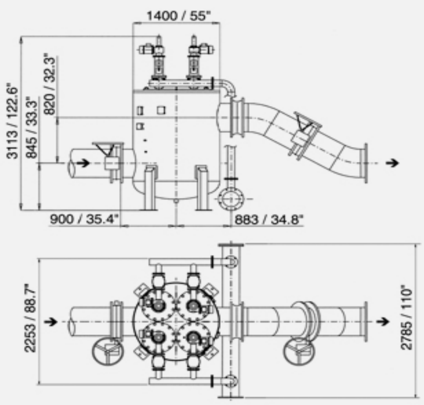
5. Irrigation type self cleaning filters

Manufacturer	Amiad
Model number	18" MegaEBS

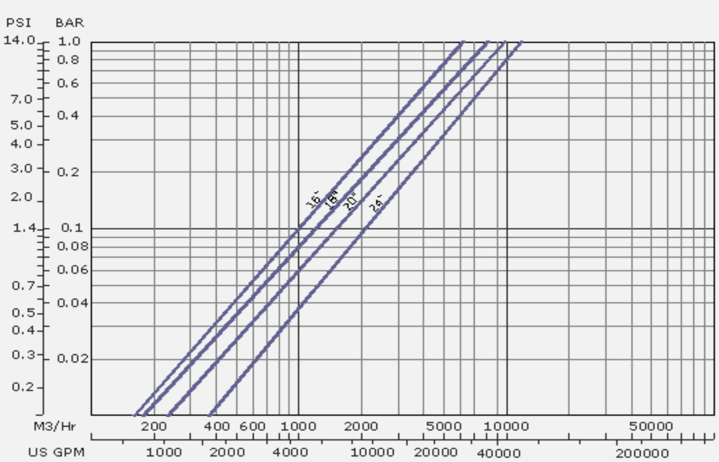
Comments:
1) Largest unit available from Amiad
2) Available in 10 to 500 um filtration - 80 um used for sizing
3) Min working pressure of 30 psi, may require pumping
4) Requires 220 to 880 gpm flushing water, and generates 530 gal per cycle
5) Screen replacement every 5-7 yrs, body replacement every 10-15 yrs (email from Eyal Yavin of Amiad to Scott Davis of HDR Jan 11, 2010)

Max flow per unit =	6,000	gpm	(prorated for 80 um)				
Flow in Feeder Canal							
Average	250	cfs	163	mgd	112,847	gpm	
Max	500	cfs	325	mgd	225,694	gpm	
min # units required =	38						
# of units required w/ spares =	46	(includes 20% extra units for downtime)					
Filter area per unit	6,200	in2					
Required filter area	1,636	ft2					
waste generation rate	530	gal/filter/cycle					
waste per day	20,140	gal/day	(assumes 1 cycle per filter per day)				

Dimensional drawing (from http://www.amiad.com/filters/EBS2_2.asp?filterNum=EBS2)

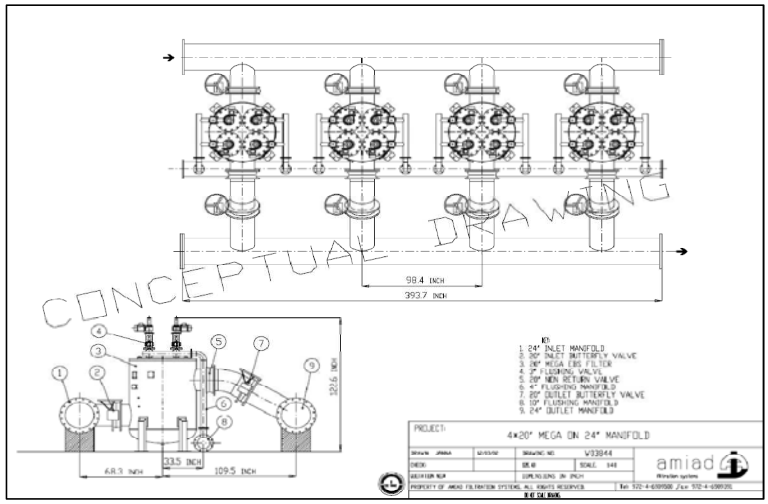


Pressure loss (from http://www.amiad.com/filters/EBS2_2.asp?filterNum=EBS2)



Pricing

email dated January 4, 2010 from Eyal Yavin at Amiad to Dedrick Damato
extrapolated based on cost of $5,000,000 for 40 - 18" MegaEBS units
equip cost $5,750,000
ballpark estimate for conceptual pricing
no manifold
water quality and pressure information required for design and price quote



Building Size

4 unit manifold			
width	15	ft	see drawing
length	33	ft	
for 10 manifolds (40 units)			
width	89	ft	
length	66	ft	
process footprint	5,833	sf	
additional (office, controls, etc)	2,917	sf	
total area	8,750	sf	
building unit cost	$300	$/sf	(includes building and footings, electrical, HVAC, etc)
cost for building	$2,624,995		

Cost Determination

pumping unit cost	$0.18	$/gpd	Lift station, RS means 2009 2nd Qtr, Union, Poughkeepsie, NY, 33.32.13.13-Cost works
pumping	$57,200,000		
filter piping, install, etc	$8,625,000		
sub-total	$74,199,995		
mod/demob, OH, profit, etc	25%		
contractor costs	$18,549,999		
subtotal cost	$92,749,993		
contingency	50%		
probable cost =	$140,000,000		

6. Rotating Drum Filter/Disc Filter

Comments:
1) Drums sit in water stream, however number of units will likely require a bypass channel with the drums
2) Largest drum screen unit is approximately 19,000 gpm
3) 90 um opening
4) Loading rate, and potential pre-treatment, would need to be confirmed for the River

Max flow rate =	19,500	gpm					
Flow in Feeder Canal							
Average	250	cfs	162.5	mgd	112,847	gpm	
Max	500	cfs	325	mgd	225,694	gpm	
# of units	14	units	(includes 20% safety margin)				
Pricing							
Drum filters	$250,000	$/unit					
Equipment Cost	$3,500,000		(vendor quote from Terry McCarthy of WMT, email dated 2-17-10 to S. Stuewe)				
			includes controls and backwash				
Building Size							
total area	625	sf	assumed (control room, spare parts, storage)				
building unit cost	$300	$/sf	(includes building and footings, electrical, HVAC, etc)				
cost for building	$187,500						
Cost Determination							
new bypass channel	$10,000,000		assumed cost for new bypass channel (excavation, grading, concrete work, supports for screens				
filter install	$3,500,000						
sub-total	$17,187,500						

7. UV Radiation

Comments:
1) Effectiveness is unknown, although UV is used to sterlize bacteria and viruses in water

Flow in Feeder Canal						
Average	250	cfs	162.5	mgd	112,847	gpm
Max	500	cfs	325	mgd	225,694	gpm

Pricing

installed UV cost	$1.22	$/gpd	(based on NYCDEP facility, $1.38B cost from website for 1.1 BGD consumption)
UV cost total	$400,000,000		includes pre-treatment
	0.0	mi	

8. CO_2

Comments:
1) Generate CO_2 rather than store
2) Dose requirement not reviewed based on review of literature showing anoxic not effective (MacNeill et al.)
3) Nitrogen gas bubbles (similar to CO_2) only had 84% kill rate at 1 week, 65% at 3 days, 55% at 2 days)

Flow in Feeder Canal						
Average	250	cfs	162.5	mgd	112,847	gpm
Max	500	cfs	325	mgd	225,694	gpm
Holding time	2	days				
Holding vol required	650,000,000	gal				
Use of off-line contact tank						
assumed channel depth	15	ft				
required area	5,793,226	ft2				
	133.0	acre				
required width	2,407	ft				
required length	2,407	ft				
Use of Canal for retention time						
assumed average channel depth	6	ft				
required area	14,483,066	ft2				
assumed average channel width	15	ft				
length of channel for contact time	965,538	ft				
	182.9	mi				

9. Chlorine Injection

Comments:
1) Use liquid hypochlorite, rather than gas
2) Dose of 5,000 mg/L required per MacNeill et al., with 1 hr contact time
3) For comparison, reasonable dose of 5 mg/L is costed, although this would require verification

Flow in Feeder Canal						
Average	250	cfs	162.5	mgd	112,847	gpm
Max	500	cfs	325	mgd	225,694	gpm
Holding time	1	hr				
Holding vol required	13,541,667	gal				
Use of off-line contact tank						
assumed channel depth	15	ft				
required area	120,692	ft2				
	2.8	acre				
required width	347	ft				
required length	347	ft				
Use of Canal for retention time						
assumed average channel depth	6	ft				
required area	301,731	ft2				
assumed average channel width	15	ft				
length of channel for contact time	20,115	ft				
	3.8	mi				

Chem dose	5,000	mg/L	
Hypo usage (12.5%)	13,000,000	gpd	
Bisulfite dosing (38%)	5,986,842	gpd	(1.4:1 dosing for dechlor)
Pricing			
Hypo storage tank	65,000,000	gal	assumes 5 day storage
Hypo tank cost	$162,500,000		assumes $2.50/gal for tank
Bisulfite storage tank	29,934,211	gal	assumes 5 day storage, same volume as hypo)
Bisulfite tank cost	$74,835,526		assumes $2.50/gal for tank
Building Size			
total area	2,500	sf	assumed
building unit cost	$300	$/sf	(includes building and footings, electrical, HVAC, etc)
cost for building	$750,000		

Cost Determination
9a uses a holding tank for retention followed by dechlorination of the tank effluent
9b uses the channel for contact time and natural consumption of residual chlorine, so no dechlorination

	9a	**9b**	
	w/ dechlor	w/o dechlor	
piping, install, holding tank, etc	$34,854,167	$1,000,000	(use $2.5/gal)
sub-total	$272,939,693	$239,085,526	
mod/demob, OH, profit, etc	25%	25%	
contractor costs	$68,234,923	$59,771,382	

subtotal cost	$341,174,616		$298,856,908
contingency	50%		50%
probable cost =	$512,000,000		$449,000,000
Annual Chemical Cost			
Hypo unit cost	$1.05	$/gal	average cost in area
Hypo cost	$13,650,000	$/day	
Bisulfite unit cost	$2	$/gal	assumed
Bisulfite cost	$12,572,368	$/day	
	$5,584,000,000	$/yr	assume Canal open 7 months

Chem dose	5	mg/L	
Hypo usage (12.5%)	13,000	gpd	
Bisulfite dosing (38%)	5,987	gpd	(1.4:1 dosing for dechlor)
Pricing			
Hypo storage tank	65,000	gal	assumes 5 day storage
Hypo tank cost	$162,500		assumes $2.50/gal for tank
Bisulfite storage tank	29,934	gal	assumes 5 day storage, same volume as hypo)
Bisulfite tank cost	$74,836		assumes $2.50/gal for tank
Building Size			
total area	2,500	sf	assumed
building unit cost	$300	$/sf	(includes building and footings, electrical, HVAC, etc)
cost for building	$750,000		

Cost Determination

9c uses a holding tank for retention followed by dechlorination of the tank effluent

9d uses the channel for contact time and natural consumption of residual chlorine, so no dechlorination

	9c	**9d**	
piping, install, etc	$34,854,167	$1,000,000	(use $2.5/gal)
sub-total	$35,841,502	$1,987,336	
mod/demob, OH, profit, etc	25%	25%	
contractor costs	$8,960,376	$496,834	
subtotal cost	$44,801,878	$2,484,169	
contingency	50%	50%	
probable cost =	$68,000,000	$4,000,000	

Annual Chemical Cost			
Hypo unit cost	$1.05	$/gal	average cost in area
Hypo cost	$13,650	$/day	
Bisulfite unit cost	$2	$/gal	assumed
Bisulfite cost	$12,572	$/day	
	$5,583,179	$/yr	assume Canal open 7 months

10. Ozone

Comments:
1) Dosing requirement not known
2) Effectiveness not known
3) For preliminary sizing/cost, use 0.5 mg/L and 5 hr contact time (for zebra mussel)
4) Dosing and contact time must be determined and confirmed if this option is to be pursued

Flow in Feeder Canal

11. Heating

Comments:
1) 50% mortality in 40oC water in 10 sec
2) 95% mortality in boiling (100oC) water in 10 sec

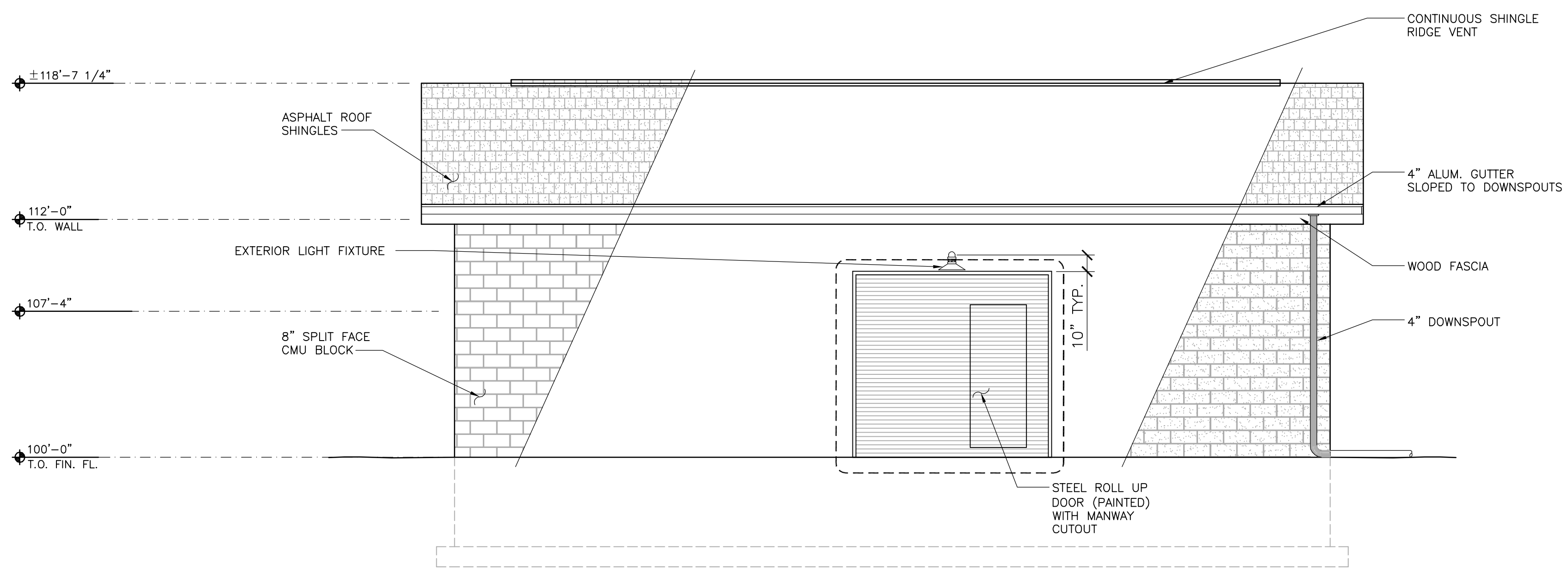
Flow in Feeder Canal

Average	250	cfs	162.5	mgd	112,847	gpm
Max	500	cfs	325	mgd	225,694	gpm

Holding time for heating	10	sec
Holding vol required for heating	37,616	gal

Holding time to cool for release - dependent on allowable discharge temperature

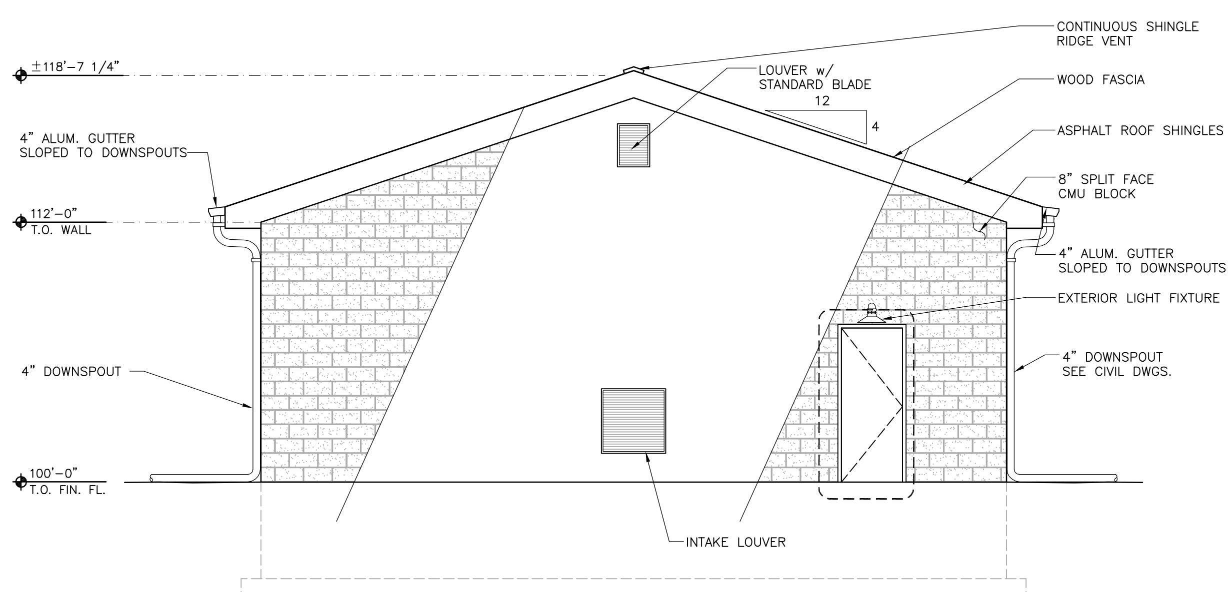
Implementation would be at least $50M for boiler building, fuel storage, etc
Energy costs would be high for boiling



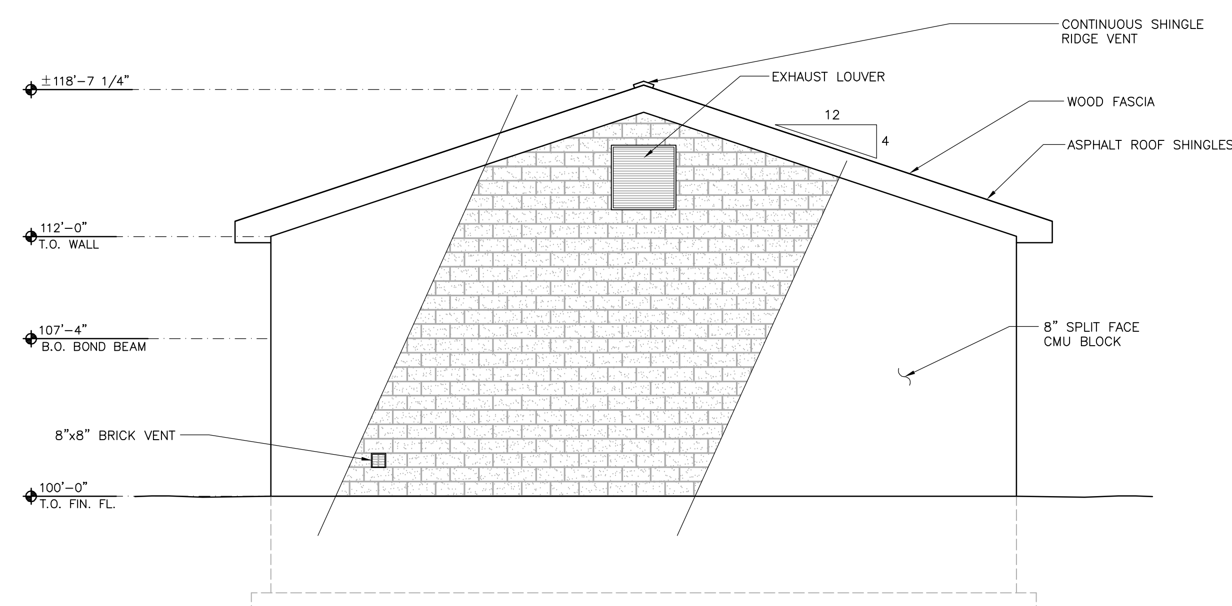
1 / A-04 **NORTH EXTERIOR ELEVATION**
SCALE: 1/4" = 1'-0"

GENERAL NOTES

1. DESIGN TO CONFORM TO THE LATEST EDITION OF THE INTERNATIONAL BUILDING CODES.
2. CONTRACTOR SHALL FIELD VERIFY ALL EXISTING CONDITIONS PRIOR TO START OF CONSTRUCTION.



2 / A-04 **WEST EXTERIOR ELEVATION**
SCALE: 1/4" = 1'-0"



3 / A-04 **EAST EXTERIOR ELEVATION**
SCALE: 1/4" = 1'-0"

HDR
Henningson, Durham & Richardson, Architecture and Engineering, P.C. In Association with HDR Engineering, Inc.

ISSUE	DATE	DESCRIPTION

PROJECT MANAGER

PROJECT NUMBER

SIGNATURE DATE

WARNING: It is a violation of the New York State Education Law for any person unless acting under the direction of a licensed professional engineer, to alter any item on these plans in any way. If alterations to these plans are made, the alterations shall be made in accordance with 145-subsection 7209 of the New York State Education Law.

GLENS FALLS FEEDER CANAL
GUNDER BOOM SUPPORT SHED

ARCHITECTURAL EXTERIOR ELEVATIONS

0 4' 8'

FILENAME A-01.DWG
SCALE N.T.S.

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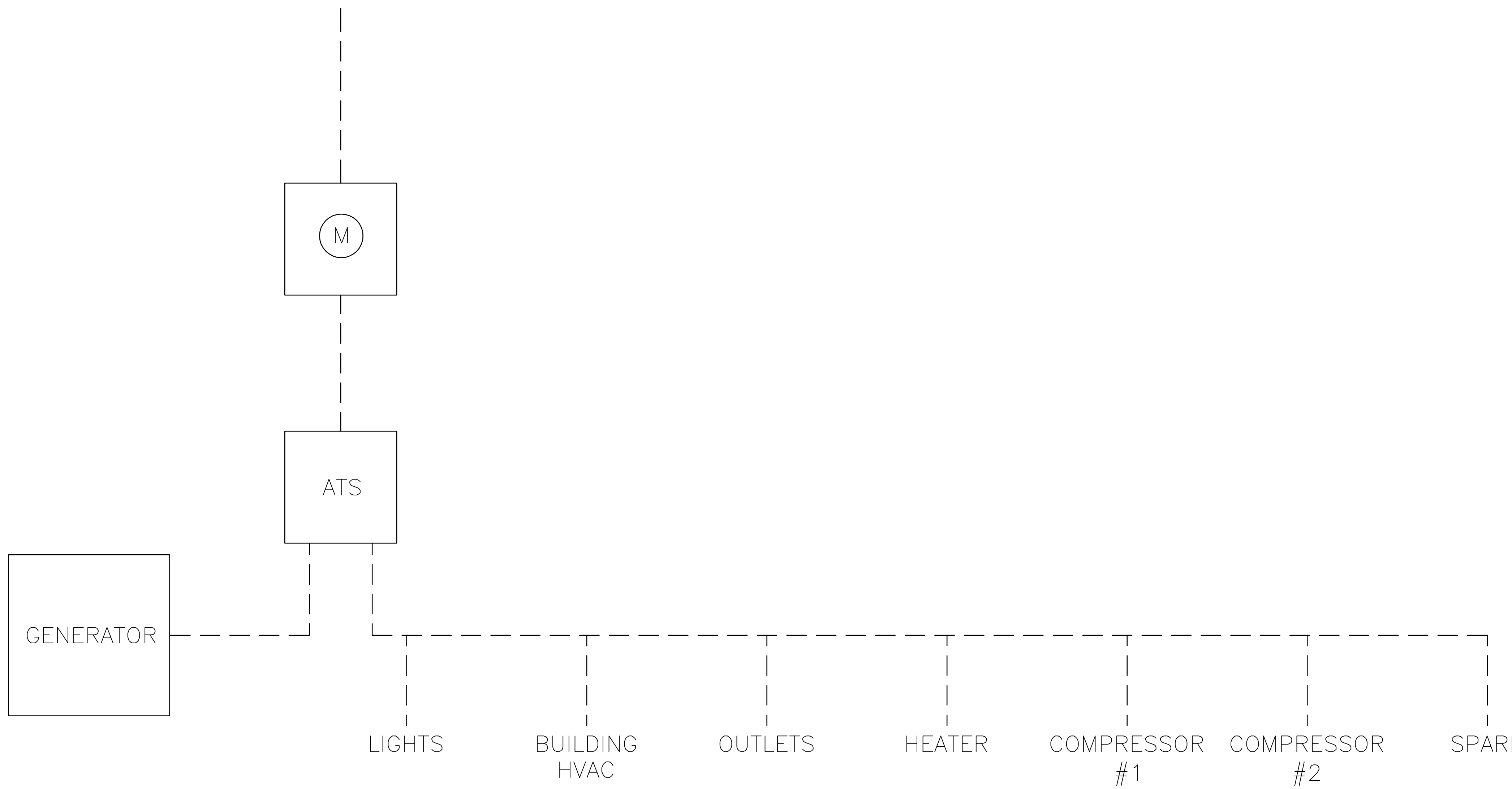

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PROJECT NUMBER	

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GLENS FALLS FEEDER CANAL
GUNDER BOOM SUPPORT SHED

ELECTRICAL

0 4' 8''

FILENAME	ELECTRICAL.DWG
SCALE	N.T.S.

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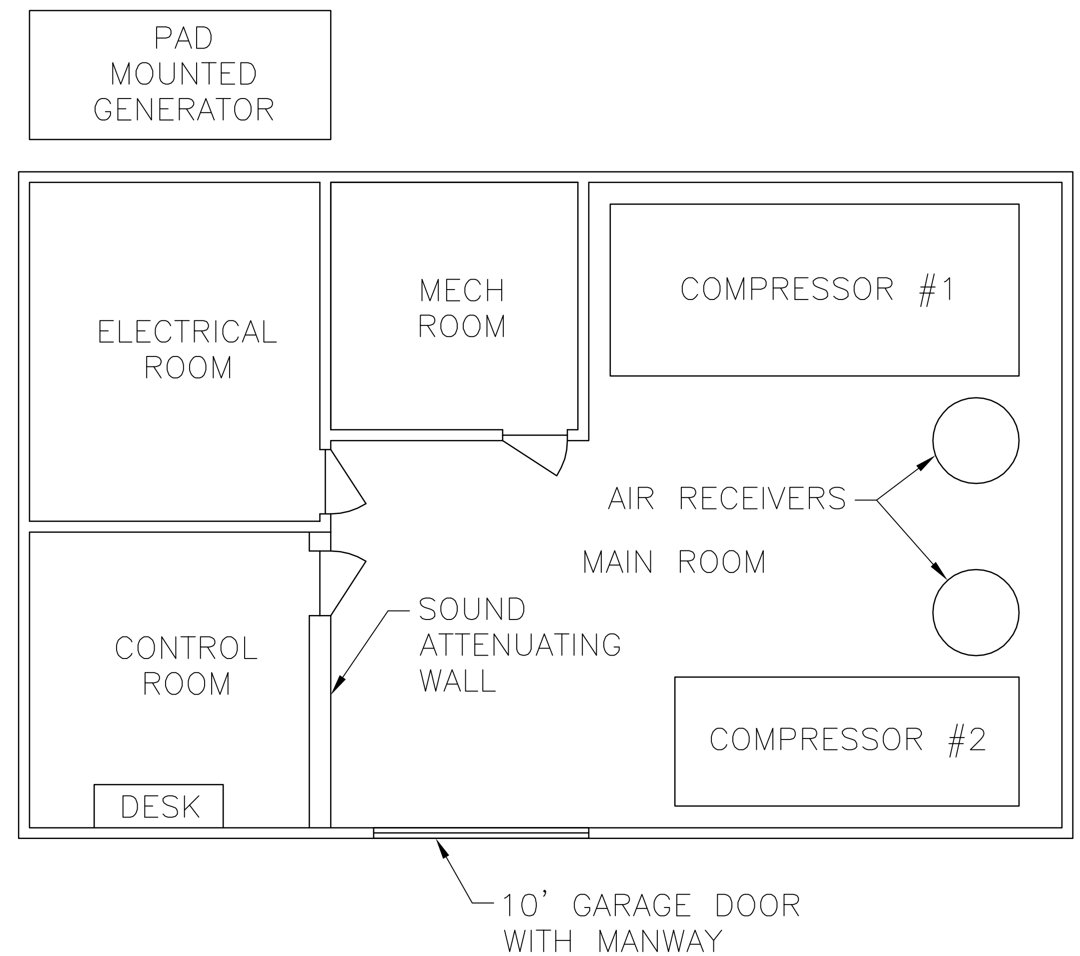

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GLENS FALLS FEEDER CANAL
GUNDER BOOM SUPPORT SHED

GUNDER BOOM FLOORPLAN

0 4' 8'

FILENAME GUNDER BOOM–FP.DWG

SCALE N.T.S.

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Detailed Gunderboom Estimate

			Unit	Qty	Unit cost	Total	
Division	***1***	***General Requirments***					
		Assumed to be 10%	%		10%	$235,479	
Division	***2***	***Site Work***					
		Building Construction	sf	1500	$300	$450,000	warwick well 2 estimate for process building, including footings, plumbing, HVAC, electrical
Division	***11***	***Equipment***					
		Gunderboom, air flushing, and anchors	sf	45,139	$27	$1,203,704	price/sf based on quote from Gunderboom
		Compressors	EA	2	$50,000	$100,000	
		Mechanical Install	%		20%	$260,741	
Division	***15***	***HVAC***					
		General HVAC cost				--	Included in building cost
		General Plumbing				--	Included in building cost
Division	***16***	***Electrical***					
		Backup Generator Diesel 100KW	ea	1	$39,570	$39,570	RS Means Building cost data 2010 pg 544 26.32.13.13.2300
		Building Electrical					Included in building cost
		SCADA and Instrumentation	%		20%	$260,741	
		Process Electrical Install	%		10%	$40,031	
		Project Sub Total				$2,590,265	
		Bonds & Insurance	3%			$77,708	
		Overhead and Profit	15%			$400,196	
		Sub total				$3,068,169	
		Contingency	50%			$1,534,084	
		Project total				$4,602,253	no land acquisition

APPENDIX B: Example Treatment Technologies

INFILCO

ABW®
Automatic Backwash Filter

PROVEN | TERTIARY FILTRATION | REUSE | LOW HEAD FILTER

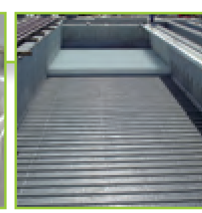
← Applications

- Tertiary Filtration
- Potable Water Filtration
- GAC Contactor
- Industrial Process Water

New and Improved! We've improved our ABW Quickplate™ Filter underdrain with a unique, two-piece cell design that virtually eliminates media leaks and offers increased strength, greater media-depth flexibility, and reduced maintenance. Easy to install, it directly replaces current configurations.

MAIN FEATURES

- → Regular, short - duration backwash
- → Low Head, shallow, simple construction
- → Excellent effluent quality - Low TSS or turbidity
- → Corrosion resistant internals
- → Improved underdrain media retention
- → Eliminates pipe galleries, backwash controller, storage, backwash holding tanks
- → Simple to operate and easily maintained



SEPARATION TECHNOLOGY: ABW® AUTOMATIC BACKWASH FILTER

The ABW® Automatic Backwash Filter means economical traveling bridge performance for municipal and industrial applications. The low-head, shallow-bed design takes advantage of surface filtration to dramatically reduce construction and maintenance costs. Our exclusive seven-stage backwash process lets the filter remain on-line during cleaning for optimum performance without shutdowns. Suitable for tertiary treatment of municipal wastewater, potable water treatment, industrial water treatment, aquifer recharge, and water reuse, the ABW® Automatic Backwash Filter is proven in thousands of installations worldwide.

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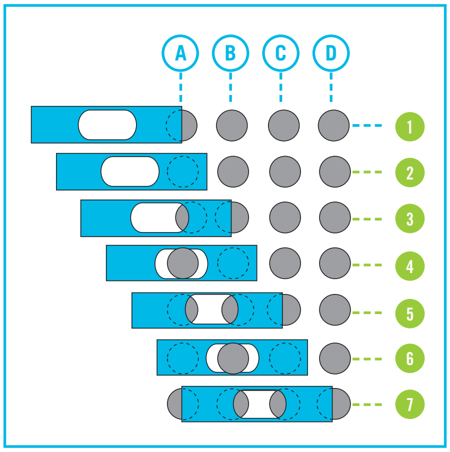
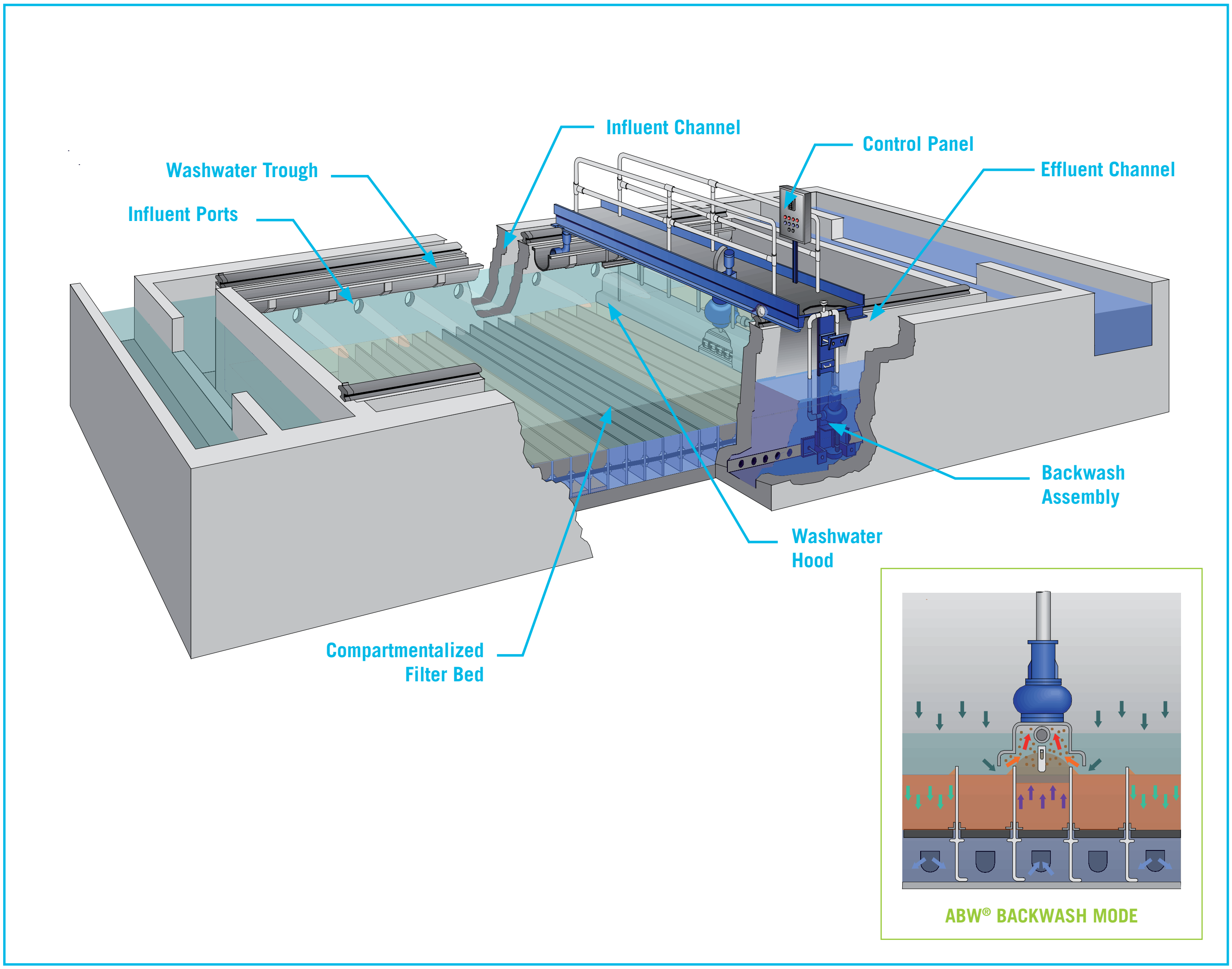
EXCLUSIVE, SEVEN STAGES BACKWASH

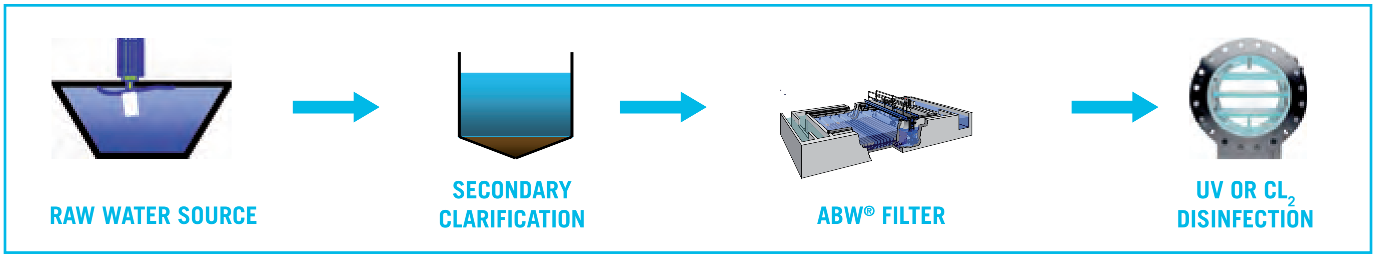


Carefully controlled media cleaning focuses on one cell at a time to optimize solids removal.

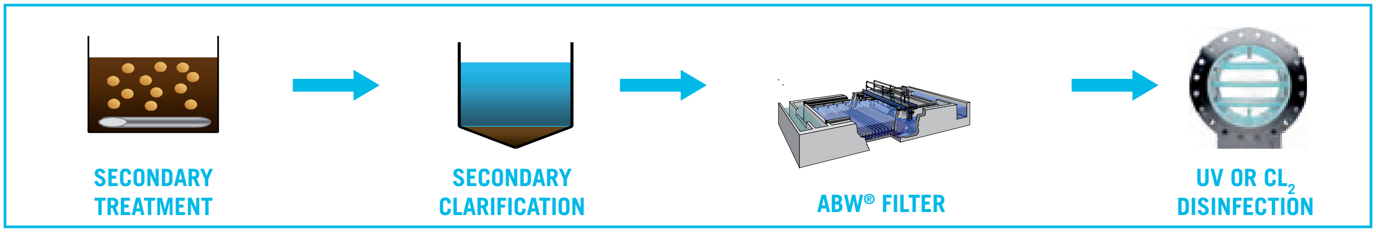
1. Filter flow through the cell is gradually reduced
2. A quiescent period allows the cell to stabilize
3. Backwash flow is gradually introduced
4. Backwash flow reaches peak rate
5. Backwash flow is gradually reduced allowing uniform media settlement
6. Backwash flow stops to let media settle completely
7. Filtration is gradually reintroduced

THE ORIGINAL AUTOMATIC BACKWASH FILTER





DRINKING WATER



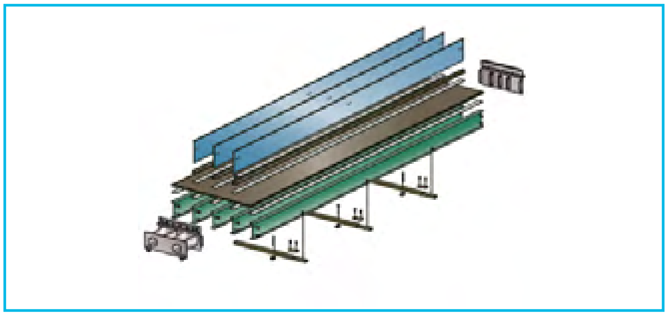
WASTEWATER

ABW® PERFORMANCE ADVANTAGES

- **Shallow penetration and low driving head** prevent solids from packing in media for easier removal.
- **Unique backwash design** eliminates backwash storage tank, control valves, pipe gallery, surge storage, and large-horsepower pumps.
- **Low head operation** simplifies basin and piping specifications for less expensive excavation and installation.
- **Regular, short-duration backwash** reduces hydraulic loading rates for lower operating costs.
- **Carriage-mounted assembly** is easy to inspect and service, and can usually remain on-line during maintenance.
- **Carefully controlled fluidization** provides bed regeneration by eliminating solids breakthrough.
- **Title 22 Approved!**

QUICKPLATE™ ADVANTAGES

- Reduced risk of media leaks due to a strong positive seal and elimination of caulked butt or ledge joints and hold down angles.
- Increased underdrain strength through I-beam supported porous plates.
- Easier installation because of a simplified grouting procedure and low profile bottom cell dividers. Fewer porous plates required.
- Increased flexibility in media depth due to a bolt-in-top cell divider.
- Direct replacement of existing design.
- Reduced labor requirements.



Quickplate™ UNDERDRAIN

DESIGN OPTIONS

- **Programmable Floating Skimmer:** for applications that involve extensive surface scum. Operates only as needed for minimal energy consumption.
- **Dual Backwash Carriages:** reduce backwash duration by up to 50% for heavy solids or large basin applications with our special tandem-operating design.
- **Pre-Wash System:** our patented pre-wash system allows the periodic introduction of a strong cleaning agent and/or a biocide prior to backwash.
- **Filtrate-to-Waste Mode:** this continually operating pump-and-piping system is kept separate from the backwash assembly to eliminate possible contamination of backwash water. When operated with this patented option, ABW® is the only traveling bridge filter approved by the EPA for potable water treatment.
- **Package Filter System:** easy to install on a concrete pad and self-contained in a steel tank, the ABW® Package Filter requires only pipe connections, electrical power, and media.

COMPLETE TREATMENT SOLUTIONS

Infilco Degremont offers an array of water, wastewater and industrial treatment solutions for any size client. Headworks, clarification, filtration, biological and disinfection systems are several of the product disciplines in our portfolio.

With a variety of filtration and clarification products in our SEPARATIONS department, Infilco engineers carefully evaluate each application to provide the most cost-effective and efficient treatment solution.

If interested in this product, check out some of the complementary SEPARATIONS products:

- Superpulsator® Clarifier
- AquaDAF® Clarifier
- Accelator® Clarifier/Softener
- Greenleaf Filter System
- Tetra™ Block Underdrains
- Monoflor® Nozzle Underdrains
- Pulsapak - Package Clarifier/Filter System
- Aquapak® - Package Clarifier/Filter System
- Accelapak® - Package Clarifier/Softener/Filter
- DensaDeg® Clarifier/Thickener

PILOTING SERVICES

Infilco offers pilot systems and services for this and many other of our product offerings. Pilot studies are a practical means of optimizing physical-chemical and biological process designs and offer the client several benefits, such as:

- Proof of system reliability
- Optimal design conditions for the full-scale system
- Free raw water lab analysis
- Regulatory approval

If interested in a pilot study for this system, please contact us for a proposal.

SERVICES

Part Sales

Infilco Degremont sells parts and components for most INFILCO brand equipment as well as parts for demineralizers, thickeners, nozzles, pressure filters, and valves. We offer reliable spare parts at competitive prices. We maintain records of previous installations to quickly identify your requirements. Many items are shipped directly from stock for quick delivery.

Rebuilds, Retrofits and Upgrades

Infilco Degremont offers cost-effective rebuilds and upgrades for INFILCO provided systems, no matter what year they were built. If you are interested in an economical alternative to installing a whole new system, contact us for a proposal.

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Fax: +1 514 683 1203
info-canada@degtec.com

Manufacturers' Representative:

INFILCO

AQUADAF®
Clarifier

HIGH–RATE CLARIFICATION | MEMBRANE PRETREATMENT | ALGAE REMOVAL | TOC/COLOR REMOVAL

← Applications

- Drinking Water Clarification
- Membrane (UF, MF, RO) Pretreatment
- Tertiary TSS and Phosphorous Removal
- TOC and Color Removal
- Cold Water Treatment
- Conventional Basin Retrofit
- Desalination Pretreatment
- Filter Backwash Recovery/Thickening

AquaDAF® is a high-rate clarifier for low-turbidity and algae-laden surface waters. The AquaDAF® clarifier's uniquely engineered effluent collection system provides operating rates unequaled by conventional flotation technologies. The result is increased capacity for existing or new treatment facilities with no minimal space required.

MAIN FEATURES

- → Compact footprint - 10 to 20 gpm/ft^2 DAF loading rate
- → All stainless steel recycle system
- → No, or limited, polymer use
- → Start-up & shutdown within minutes
- → Ideal membrane pretreatment technology - increased flux rates
- → Hydraulic or mechanical sludge removal options

AquaDAF® CLARIFIER SPECIFIC TECHNOLOGY

Dissolved Air Flotation (DAF) is an excellent solution for clarifying water with high levels of algae and other low-density solids that cannot be removed efficiently by sedimentation. The AquaDAF® clarifier combines conventional DAF principles with several enhanced components, including a unique effluent collection system. This and other process improvements allow efficient hydraulics within the DAF flotation zone at superior surface loading rates.

suez environnement | Degrémont

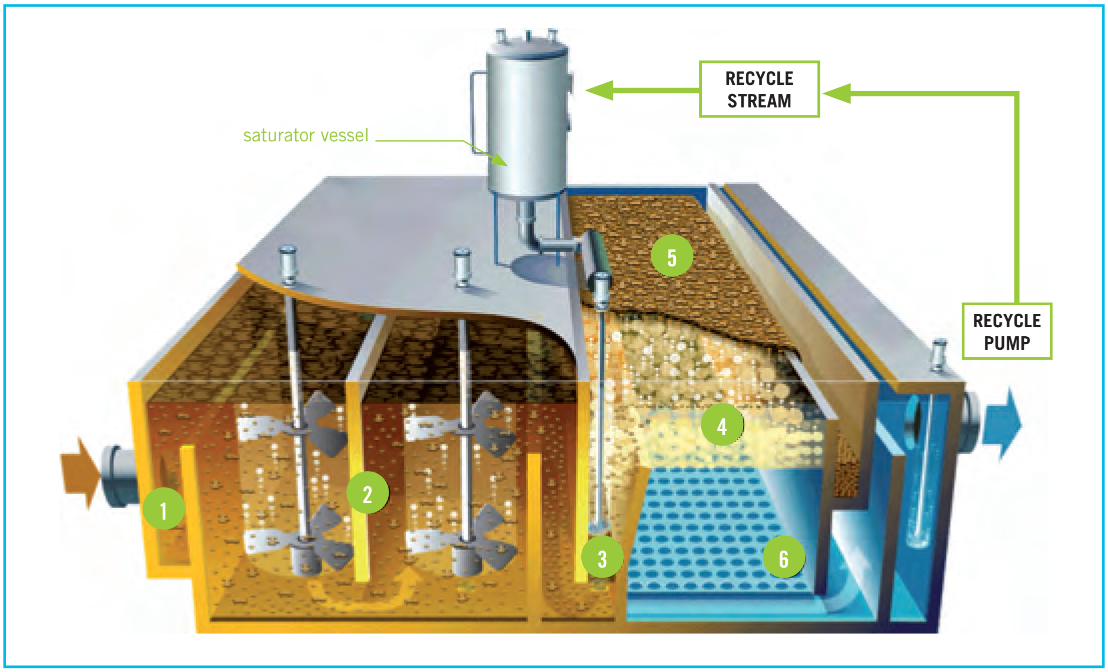
HOW IT WORKS

1 **RAW WATER INLET:** Coagulated water from an in-line rapid mixer enters a flow distribution channel prior to the flocculation zone. Coagulation is the destabilization of colloidal particles, which facilitates their aggregation and is achieved by the injection of a coagulant, such as alum or ferric chloride.

2 **FLOCCULATION ZONE:** Coagulated water is equally split to each unit, with traditional 2-stage tapered energy flocculation with variable frequency mixers. In this step, the destabilized particles agglomerate and form larger floc particles. The AquaDAF® flotation process requires only the formation of light, pinpoint particles, eliminating or significantly reducing the need for flocculant polymers. Additionally, the retention time employed in this stage is generally between 8 to 10 minutes.

3 **AIR-WATER DISPERSION ZONE:** Flocculated water is then transitioned to the base of the flotation zone, where it passes through the injection of a saturated air-water recycle stream. This recycle stream is produced by recycling 8-12% of clarified or filtered water to a pressurized saturator vessel (70 to 90 psi). The recycle stream is then depressurized through a series of release nozzles, which are submerged and span the entire width of this transition zone. This depressurization creates thousands of micro bubbles, which disperse into the flotation zone.

4 **FLOTATION ZONE:** The principle behind the flotation process is the micro-bubbles which will form a dense air blanket within the flotation zone. The flocculated particulate will agglomerate with the micro-bubbles, as they rise to the surface, subsequently clarifying the water.



AquaDAF®

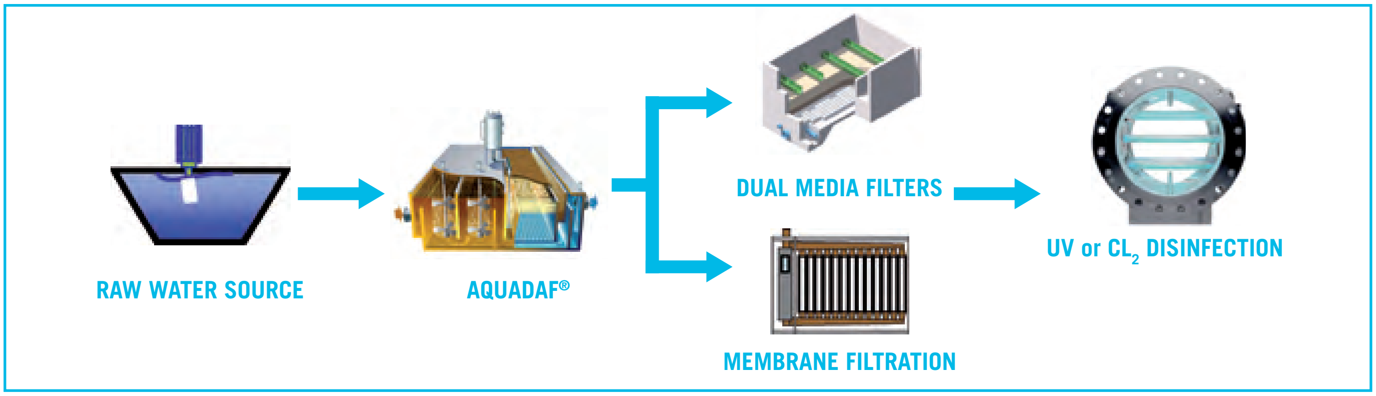
5 **SLUDGE ACCUMULATION:** The floated solids accumulate on the surface of the AquaDAF® resulting in a thick sludge layer. Sludge may be removed with one of two methods:

- Hydraulically, whereby an automatic effluent weir rises in a prescribed time. Subsequently, the flotation zone water level rises and the sludge is removed to an integral sludge trough.
- Mechanically, whereby a traveling bridge scraper mechanism will penetrate and scrape the solids layer into the integral sludge trough.

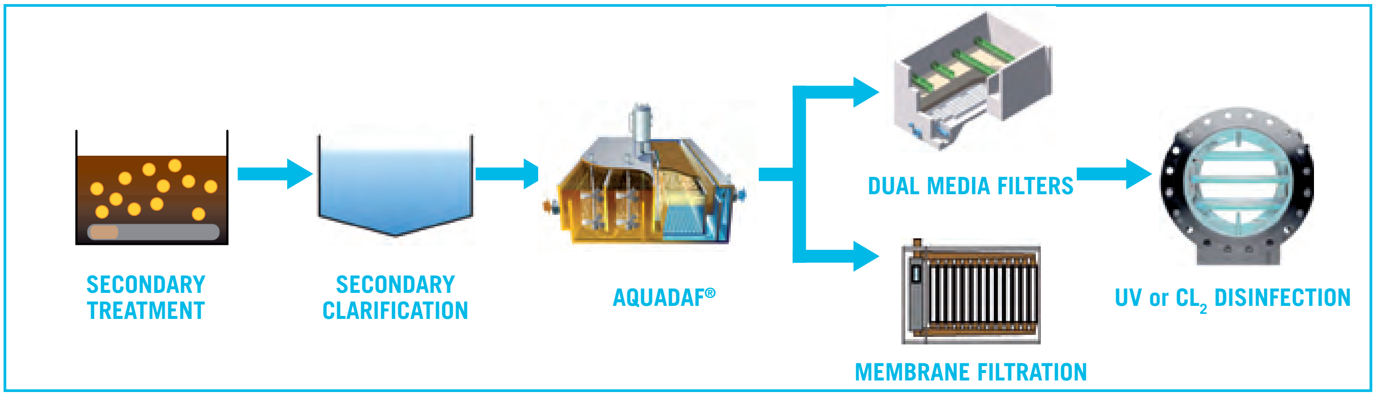
6 **COLLECTION:** Clarified water is collected uniformly across a perforated collection floor. This uniquely engineered system, in combination with other process enhancements, creates resistance over the flotation zone, resulting in uniform collection and efficient hydraulics throughout the basin. The result is the ability to handle high downward velocities and DAF loading rates significantly higher than conventional DAF processes.

Product Highlights

- → Efficient removal of low-density particles
- → Polymer-free membrane pretreatment
- → Clarification of water with low turbidity
- → Cold water treatment
- → Filter backwash applications



DRINKING WATER - CLARIFICATION



TERTIARY WASTEWATER – PHOSPHORUS & TSS REMOVAL

PERFORMANCE ADVANTAGES

- Clarified turbidity less than 1 NTU
- Algae removal greater than 90%
- Flocculation time of less than 10 minutes
- Phosphorus removal less than 0.1 mg/l TP
- Thickened sludge of 2-4 %

DESIGN SPECIFICATIONS

	Single Unit Capacity
AquaDAF® 10 - 20 gpm/ft^2	MGD
	0.5 to 25

DESIGN OPTIONS

- Hydraulic or mechanical sludge removal
- Package Systems - Nine standard package units from 100 gpm to 1,750 gpm (with or without filters)

Technical Features

→ Flexible layout options
→ Customize to any size plan
→ Loading Rates: 10 to 20 gpm/ft^2
→ No or limited polymer use
→ Polymer-free membrane pretreatment
→ Efficient for cold water clarification
→ Unit heights 10 to 14 feet
→ Start-up and shutdown within minutes
→ Retrofit existing sedimentation basins
→ Common-wall layout with our Greenleaf® Filter

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- DensaDeg® Clarifier/Thickener
- Monoflor® Nozzle Underdrains
- ABW® Automatic Backwash Filter
- PulsaPAK® Package Clarifier/Filter System
- AquaPAK Package Clarifier/Filter System
- AccelaPAK® Package Clarifier-Softener/Filter

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Fax: +1 514 683 1203
info-canada@degtec.com

Manufacturers' Representative:

OZONIA

AQUARAY® H_2O

UV Systems for Drinking Water

UV DISINFECTION | MEDIUM PRESSURE | US EPA VALIDATED | DRINKING WATER

← Applications

- Drinking water disinfection

← Main characteristics

- Bioassay tested with MS2 and T1 phage
- High capacity with a low number of medium pressure UV lamps
- Dedicated and calibrated UV intensity sensors to ensure optimum reliability
- Automatic wipers for quartz sleeve cleaning
- Meets all US EPA and DVGW guidelines

Aquaray® H_2O UV systems are able to treat from 2 to 55 MGD.

MAIN FEATURES

→ **Optimized performance:**
The Aquaray® H_2O has been optimized with CFD modeling software to maximize UV dose and minimize head loss.

→ **Energy conservation:**
Due to the variable electronic ballasts, the total power can be adjusted based on the exact flow and water quality characteristics.

→ **Save space:**
To minimize the footprint, the Aquaray® H_2O uses Medium Pressure UV Lamps with a high power density.

→ **Validated performance:**
The Aquaray® H_2O has been third party validated and obtained DVGW and/or US EPA certification following strict bioassay testing.

UV TECHNOLOGY: Aquaray® H_2O

The Aquaray® H20 UV systems have been designed to disinfect drinking water. The germicidal effect of the UV light inactivates most micro-organisms such as bacteria, viruses and parasites. UV is known to be particularly efficient to inactivate *Cryptosporidium Parvum* and *Giardia Lamblia.*

The UV dose (UV intensity x contact time) defines the treatment efficiency which is provided by the unit. The effective dose applied depends on the UV transmittance of water to be treated as well as the proper hydraulic design of the unit.

HOW IT WORKS

The medium pressure lamps are powered by electronic ballasts. The lamps are inserted in pure quartz sleeves isolating them from the water. The lamps can be easily changed without draining the reactor.

DVGW approved UV sensors are installed to monitor UV intensity. Easy access to all components allows for rapid and simple maintenance.

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TECHNICAL DATA

Model	Number of reactor	Peak Flow Rate	Number of lamp	Electrical Power per lamp	Installed Electrical Power
		MGD		kW	kW
Aquaray® H_2O 20"	1	9	6	4	24
Aquaray® H_2O 'Duplex' 20"	2 (in series)	18	2 x 6		48
Aquaray® H_2O 36"	1	55	10	8	80

- **Lamp Type:** medium pressure
- **Ballast Type:** electronic variable output (20-100%)
- **Sensor Type:** DVGW approved
- **Lamp configuration:** horizontal cross flow
- **Average lamp life:** 10 000 - 12 000 hours

▶ Materials

- **Reactor material:** 316L stainless steel/quartz sleeves/ silicon O-ring
- **Panel material:** mild steel epoxy coated

▶ Standards

- **Flanges:** 20", 36"
- **Reactor pressure rating:** 150 psig
- **Main power supply:** 480V-60Hz
- **Panel rating:** NEMA 12 (standard)
- **Operation PLC:** Allen-Bradley (standard)

▶ Remote controls and alarms

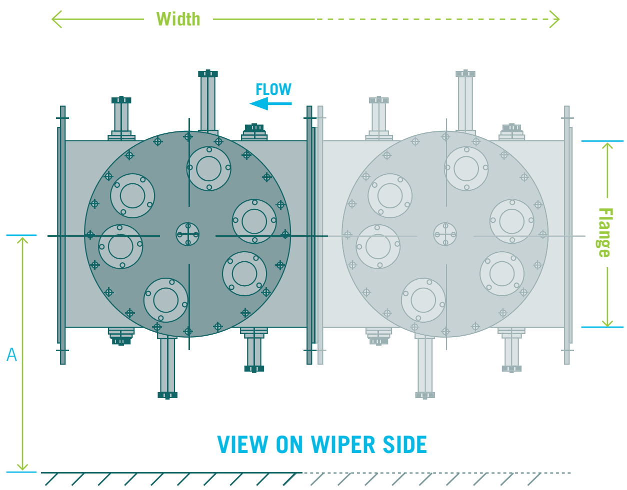
- **SCADA communication capability**
- **Numerous alarms and setpoints**

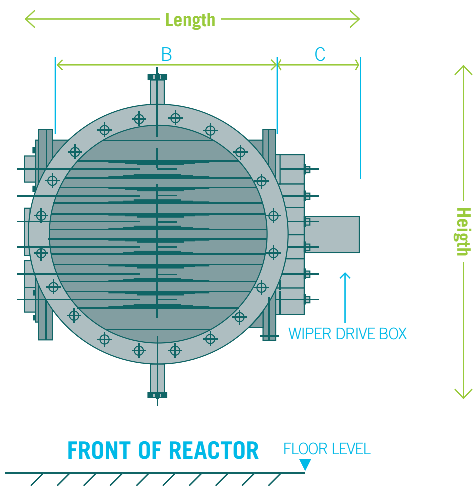
▶ Options

- **NEMA 4X**
- **Stainless steel control panel**
- **Alternate PLC and interface**

DIMENSIONS

Model	Number of reactor	Dimensions (in)			Weight	Flange	l x h x w
		A	B	C	lb	in	in
Aquaray® H_2O 20"	1	26	23.6	16.5	770	20	42.5 x 34.6 x 27.6
Aquaray® H_2O 'Duplex' 20"	2 (in series)	26	23.6	16.5	1540	20	42.5 x 34.6 x 55.2
Aquaray® H_2O 36"	1	45	40	16.5	1210	36	62 x 69 x 45.6





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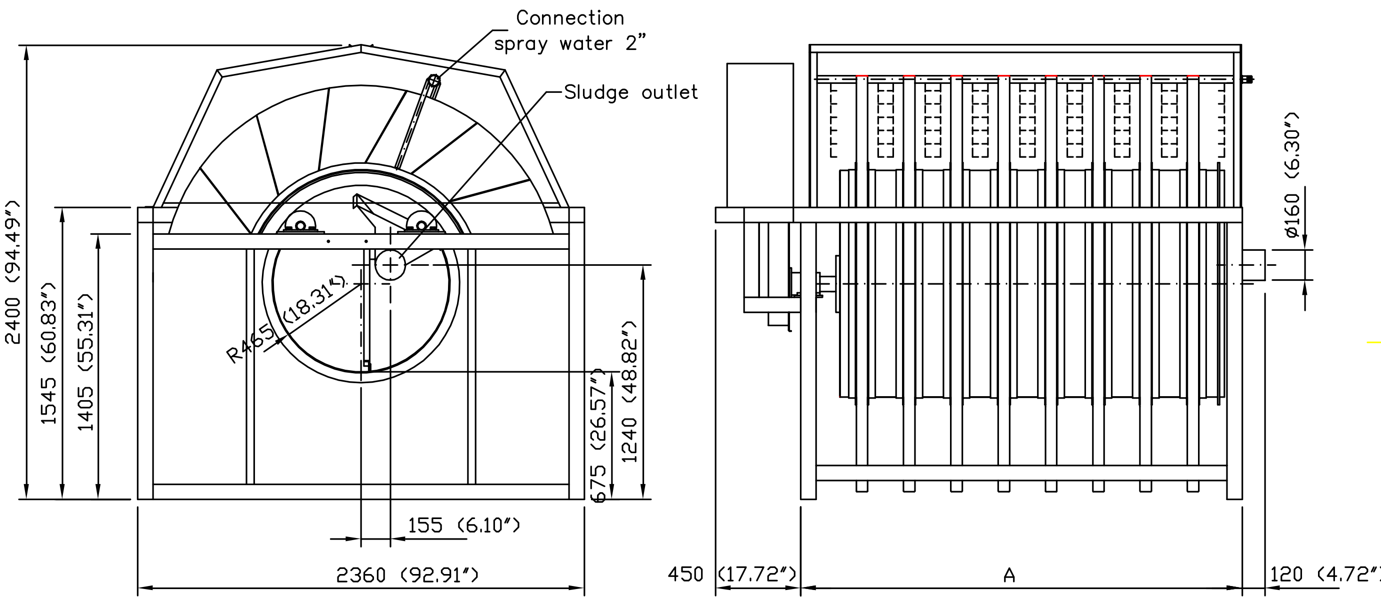
Ozonia Triogen UK	• info-triogen@degtec.com	• + 44 141 810 4861
Ozonia Russia OOO	• info-ozoniaRU@degtec.com	• + 7 831 220 3256
Ozonia Korea	• info-ozoniaKR@degtec.com	• + 82 31 701 9036
Ozonia China	• info-china@degtec.com	• + 86 10 659 73 860
Ozonia Japan	• info-japan@degtec.com	• + 81 3 544 46 361

Manufacturers' Representative:



TO SIMPLIFY MAINTENANCE, 600 MM WIDE WALKWAYS SHALL BE MOUNTED AROUND THE FILTER.

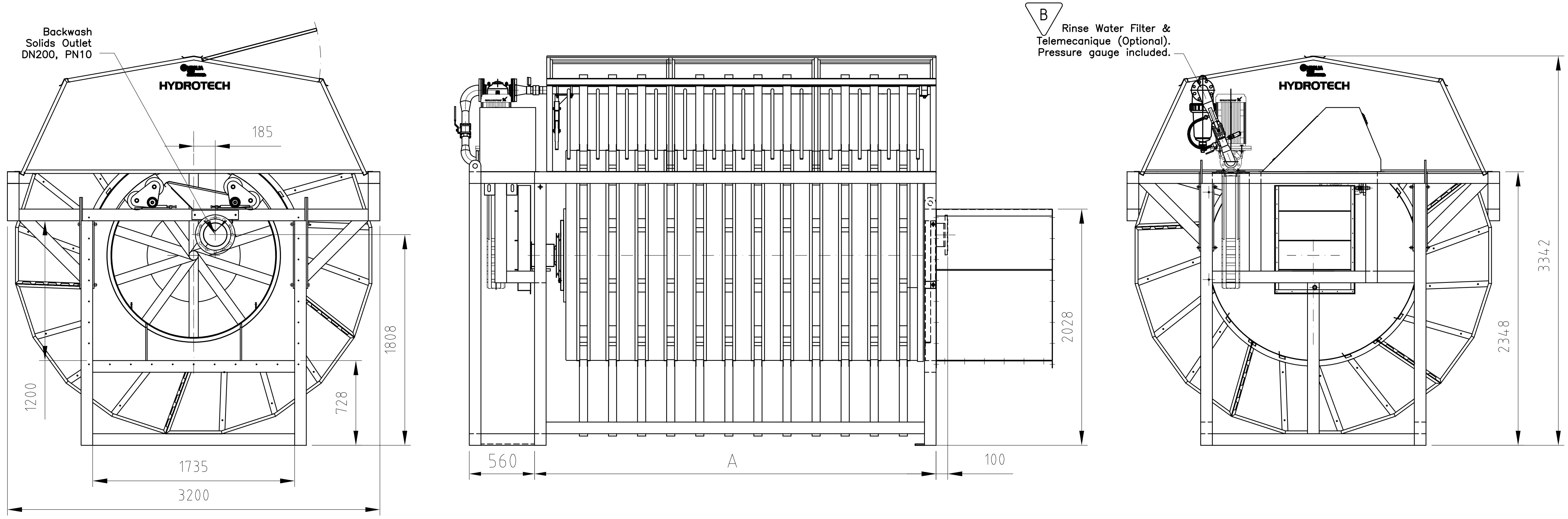
IF THE FILTER IS NOT SUPPLIED WITH COVER FROM HYDROTECH, THE FILTER SHALL BE FENCED TO AVOID ANYONE FROM COMING CLOSE TO THE FILTER UNDER ROTATION, TO AVOID INJURIES.

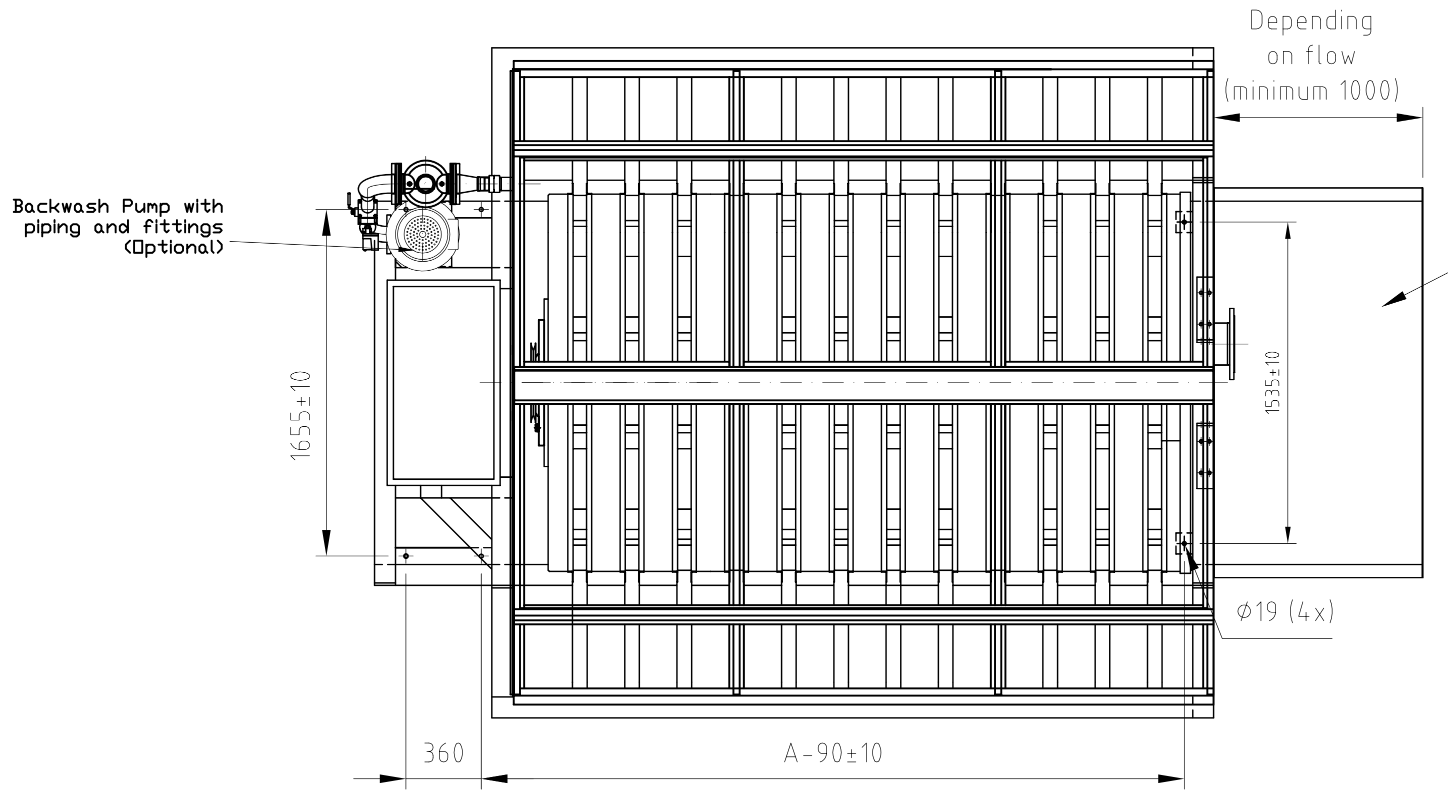
TYPE	A
2102	830
2104	1330
2106	1830
2108	2330
2110	2830

All dimensions in m.m.

Det.-nr	Ant.	Benämning			Material		Mod.-nr Zmne Dimension	Anm.	
Konstr. AM	Ritad AM	Kop.	Kontr.	Stand.	Godk.		Skala 1:20	Ersätter	Ersatt av
HYDROTECH		Measure drawing HSF2102-10 Type2H						1519	Dat. 970926
								Ritn.-nr 1519	

Nr	Ant	Ändring och/eller medd.-nr	Datum	Inf	Godk





TYPE	A
3106	1950
3108	2450
3110	2950
3112	3450

MAINTENANCE ACCESS SHOULD
BE PROVIDED TO ALL FOUR SIDES OF
THE FILTER, SIZED TO SUIT LOCAL
REGULATIONS, TYPICALLY
1000 mm, BUT NOT LESS THAN 600 mm.

WE RESERVE THE RIGHT THAT WITHOUT
ANY NOTICE TO CHANGE
THE DESIGN OF THE EQUIPMENT

Ed.	Change and/or message no.	Date	Made by	c-m no.
B	Optional Telemecanique added	090220	MaHo	

Part no.	Quantity	Name	Material	Mod.-nr Blank Dimension	Remark

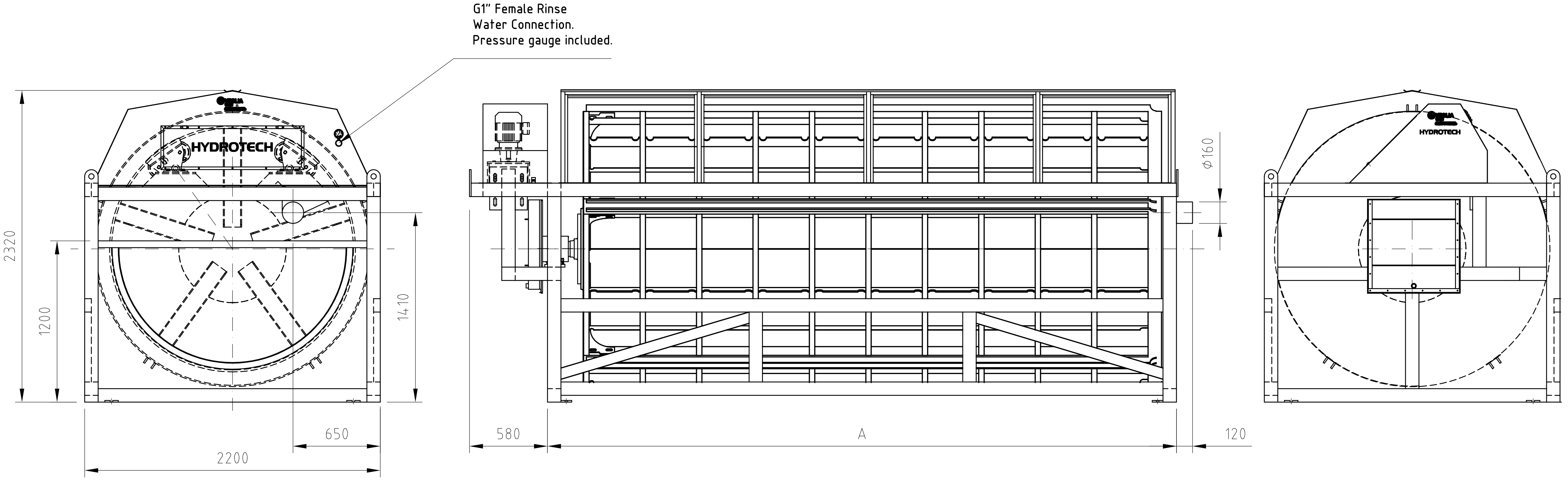
Designer: | Drawn by: ADn | Copy: | Controlled by: | Stand.: ISO 2768-m | Approved: | Scale: 1:25 | Replaces: | Replaced by:

HYDROTECH

Measure drawing
(3112 drawn)
Discfilter HSF3100-2F

Date: 050525

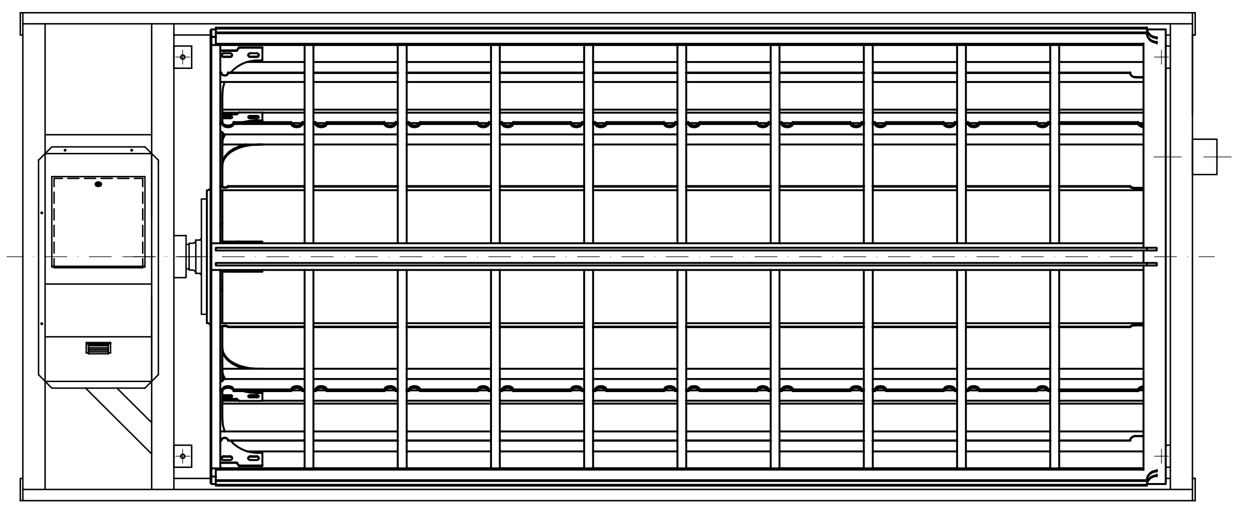
Draw. no. 3106 Edition B



TYPE	A
2008	3840
2009	4260
2010	4680

MAINTENANCE ACCESS SHOULD
BE PROVIDED TO ALL FOUR SIDES OF
THE FILTER, SIZED TO SUIT LOCAL
REGULATIONS, TYPICALLY
1000 mm, BUT NOT LESS THAN 600 mm.

WE RESERVE THE RIGHT THAT WITHOUT
ANY NOTICE TO CHANGE
THE DESIGN OF THE EQUIPMENT



Part no.	Quantity	Name	Material	Mod.-nr Blank Dimension	Remark

Designer	Drawn by	Copy	Controlled by	Stand.	Approved	Scale	Replaces	Replaced by
	AM			ISO 2768-m		1:30		

HYDROTECH

Measure drawing

Drumfilter HDF 2008-2010 2H

Date 080828

Draw. no. 3712 Edition A

Ed.	Change and/or message no.	Date	Made by	c-m no.