Essex Region Conservation Authority

BIG CREEK WATERSHED PLAN

December 2013

Essex Region Conservation Authority

AMHERSTBURG

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1.0 Executive Summary

The Big Creek Watershed has a drainage area of over 7,300 hectares (18,000 acres) and includes parts of the urban core of Amherstburg as well as rural and agricultural lands. Big Creek Marsh is the watershed's largest natural heritage feature, and consists of approximately 900 hectares (2,500 acres) of Provincially Significant Wetland (PSW) that has a controlled outlet to Lake Erie. Alterations to drainage, re-routing of watercourses, and clearing of natural features in the Big Creek Watershed since European settlement, have resulted in changes to watershed hydrology, reductions in water quality, and diminished ecological function. However, terrestrial fieldwork of the marsh areas at the southern end of the watershed contains one of the best examples of a shoreline lacustrine wetland in the Province of Ontario.

The major historical diversions of headwater areas out of the Big Creek watershed have resulted in the loss of approximately half of the original watershed area. This has substantially affected the natural hydrology and flow conditions of this watershed.

The quality and health of Big Creek is a fundamental aspect of a healthy watershed and the health of communities in the watershed. A watershed-based approach to manage natural resources is vital to the protection and sustenance of a healthy watershed. The Town of Amherstburg, in partnership with the Ontario Ministry of the Environment (MOE), the Essex Region Conservation Authority (ERCA), and a group of private hunt clubs from the watershed, initiated the Big Creek Watershed Plan. This Plan aims to affirm and/or identify and assess natural resources in the Big Creek watershed, and to recommend appropriate strategies for the protection or management of the varied natural resource values and community priorities that exist in the area. Three key watershed-based studies inform the Plan. These are the Water Quantity Report, the Water Quality Study, and the Natural Heritage Study.

Water Quantity

The quantification of water resources in the watershed is of paramount importance in developing the watershed plan. In order to undertake a comprehensive water quantity analysis of this watershed, many tools and methods have been utilized. A water budget was prepared as one of the major components of the water quantity study. In addition, the watershed's contributing sediment and nutrient loadings were also characterized using a continuous agricultural non-point source pollution simulation model. Tile drainage throughout the watershed is extensive due to the high level of agricultural land use activities and poor natural soil drainage to improve soil productivity.

The annual model results show that evaportanspiration (ET) is the largest hydrologic component of the water budget with other minor components consisting of surface runoff (water yield), tile drainage flow, and groundwater flow. During the summer period, precipitation is less than ET and water yield combined, which indicates soil moisture generally depletes during the summer season. A number of streamflow results indicate this watershed frequently experiences very low flow conditions in certain years. The lowest monthly flow occurred in the year 2005. These results, along with anecdotal observations, indicate that flow conditions in Big Creek are among the most stressed of Essex Region watersheds. This is likely due, at least in part, to the historical major diversions of headwater areas out of the Big Creek Watershed.

The water levels of the wetland have been managed to some degree since 1909, using a system of pumps, dykes, and a control dam. During the historic management period, anecdotal information suggests that the operators attempted to manage the wetland in a similar fashion to the current management period, but were limited to the resources available at that time to maintain the infrastructure.

When considering the entire study period, the two largest inputs into the marsh are streamflow and precipitation, which indicates that the largest inputs affecting this wetland are linked to the natural hydrologic cycle. The connection between Lake Erie and the Big Creek Marsh was also investigated. Over the 40 year period studied, as defined previously, the marsh water levels were higher than the lake water level (93% of the time). There is also a correlation between higher marsh water levels and lake water levels and indications that during lower lake water levels, the wetland would experience a natural drawdown period if not artificially maintained with the outlet control gate and dyke system.

Although the optimal operation of the private dam and portable pumping system may be able to sufficiently augment the water levels in the marsh, it may not be realistic to expect that this will always be feasible during prolonged and/or extreme dry periods in the future when there is little or no inflow from the upstream watershed, combined with substantial loss of water due to ET. Artificially maintained water levels in the marsh do not extend upstream to the middle and upper reaches of the watershed due to historical diversions at the headwaters. These upstream reaches will continue to be highly stressed during drought conditions.

Sediment loading results shows that clay is the largest contributor to sediment loading, and that this is to be expected as the watershed is composed primarily of clayey soils and the deposition rate of clay is the slowest. The months of April, May and June have the highest average monthly sediment yield rates, which is likely caused by spring runoff events.

The months of March, April and May have the highest monthly average total nitrogen yield. Phosphorus is not as mobile as nitrogen, but is strongly absorbed by the soil. Phosphorus that is absorbed by sediment particles may be conveyed in overland flow. The months of April, May and June have the highest monthly average total phosphorus yield.

Implementation of the Big Creek Watershed Plan will, where appropriate, reduce the impacts of sediments and nutrients on specific reaches of the watershed and the lower Big Creek basin. These initiatives will likely include well known and tested farming activities addressing crop residue management, conservation tillage practices, tile drainage and other specific treatments including buffer strips and rock chutes.

Water Quality

Although there has been a reduction in average total phosphorus concentrations since the 1960s, current levels remain significantly above the benchmark PWQO limit. The total phosphorus concentrations observed in the marsh and along the nearshore of Lake Erie were above the benchmark but significantly lower than those found within the tributaries of Big Creek. In general, the total phosphorus concentrations in the Big Creek watershed are typical of highly agricultural landscape of the Southwestern Ontario. Potential sources may include run-off from fertilized agricultural lands within the watershed and urban inputs from the Town of Amherstburg. The majority of nitrate in the Big Creek watershed originates in the northeast region of the watershed. The current levels of nitrate in the watershed appear to be similar to historical levels, well below the CEQG benchmark at all sites tested. The areas with the lowest average annual phosphorus and nitrogen yields in the watershed had land use types of forest and open water.

In general, chloride concentrations in the Big Creek watershed tend to be high compared to typical chloride concentrations observed in small streams in Essex Region. Chloride is typically indicative of road salt in urban runoff. The majority of the chloride in the Big Creek watershed originates from areas of urban runoff subjected to application of road salt. Chloride levels downstream, within the marsh and at the nearshore were normal and well below the benchmark value.

E. coli levels (an indicator of fecal contamination) tend to be higher than the recreational guideline limit within the tributaries of the Big Creek watershed but were found to be well below the benchmark within the marsh and nearshore area. Bacterial contamination due to human fecal sources was found just downstream of the urbanized area of the watershed.

With respect to heavy metals, there are high levels of iron in all of the samples, and high copper and zinc levels downstream of the urbanized area within the watershed. The majority of water samples in Lake Erie and the marsh showed metals below detectable limits. Pesticide results revealed all the pesticides below detectable limits, except that atrazine and glyphosate were found in low concentrations at all the tributary sites. The majority of water samples in Lake Erie and the marsh showed pesticides below the detectable limits.

The benthic community immediately downstream of the highly urbanized area of the watershed, showed a very poor benthic community, while the benthic community observed in the marsh was of good quality.

Based on the results of the water quality study, measures such as efficient private septic systems, proper road salt management and implementation of focused agricultural best management practices such as buffer strips, conservation tillage and soil erosion control structures (e.g. rock chutes, header tile retrofits) are recommended in order to improve and protect the water quality conditions in the Big Creek watershed.

Natural Heritage

The watershed contains the Big Creek Marsh Provincially Significant Wetland (PSW) and the Big Creek Marsh life science Area of Natural and Scientific Interest (ANSI) as identified by the Ontario Ministry of Natural Resources (OMNR), signifying one of the best examples of shoreline marsh and associated wetland in the Province of Ontario. In addition, Big Creek has been identified as an Environmentally Significant Area (ESA) and Significant Valleyland by ERCA, a Carolinian Canada Site and an Important Bird Area.

The extensive wetland area within the watershed performs the ecological function of hydrological flow, water retention and purification; receiving water from upstream, and purifying it within the wetlands before flowing out into Lake Erie or filtering through the barrier beach. The main wetland area of the Big Creek marsh basin is the primary location where sediments settle out of suspension and nutrients and bacteria are metabolized by the extensive submergent aquatic wetland plant community.

The watershed exhibits extremely high diversity with respect to the number and types of vegetation communities, containing 115 vegetation types according to the Ecological Land Classification (ELC) System for Southern Ontario. Vegetation community composition is 63% wetland/aquatic and 37% terrestrial. A total of 10 significant communities ranked as provincially rare occupy almost one quarter of the entire watershed area surveyed. The most significant of these communities is a 214 hectare (529 acre) American Lotus Floating-leaved Shallow Aquatic vegetation community which occupies over 16% of the watershed area surveyed. This may indeed be the largest population of this provincially rare plant and vegetation community in Ontario.

Floristically, the watershed's flora is relatively intact with high floristic quality, an extremely rare condition representing a significant component of Ontario's native biodiversity and natural landscapes. A total of 562 plant species were identified; 56 of which are significant floral species with five species which are listed as Species at Risk.

A total of 259 animal species were identified. Sixty six (66) are significant faunal species; nine of which are listed as Species at Risk. The Big Creek watershed contains colonial bird nesting sites. The open water wetlands are significant as a waterfowl stopover and staging area, while the diverse upland areas within the watershed provide landbird migratory stopover areas as well as stopover habitat for the Monarch butterfly. Some areas within the watershed provide Turkey Vulture summer roosting areas as well as suitable areas of reptile hibernacula. The faunal inventory recorded the presence of area-sensitive bird species in areas of forest which are extensive enough to provide interior forest habitat.

Finally, it is important to note that this very extensive and diverse wetland is extremely productive with respect to wildlife breeding, especially marsh birds. The conditions which lend themselves to this area being such an extremely productive wetland are largely due to the fact that most of the wetland area is privately owned and managed. This wetland would not be as productive biologically if this area was intensively used by the public during the breeding season. The current owners and managers are to be commended for their outstanding stewardship and management of their properties.

2.0 Introduction

There is a need to manage and plan for the appropriate use of the natural environment and its resources. As development continues across the landscape, sustainable management and appropriate planning are required to ensure that current and future actions do not degrade, negatively alter or destroy the natural environment. A watershed plan is an effective planning tool used to ensure that current and future generations are able to progress while acknowledging and addressing changes to the local ecosystem.

> A watershed is the region of land draining into a river, river system, or other body of water.
>
> The purpose of watershed planning is to balance environmental protection, conservation, and restoration with development and land use, ensuring long-term ecological sustainability of the watershed and its significant natural features.

The Town of Amherstburg and the region have experienced tremendous changes and growth over the past several decades, which have impacted on the region's water resources. Increased need to access surface and groundwater and changes to the urbanizing and agricultural areas of Amherstburg has resulted in water management demands and conflicts and the need to understand the complex watershed environment.

The interconnections between human activities on land, natural heritage, water quantity, and water quality can best be assessed, managed and monitored through integrated watershed management (IWM). Through IWM, the environment and resources contained within a watershed are managed to preserve the natural values important to individuals and society and ensure that our continued use of the resources are sustainable. This includes a healthy aquatic ecosystem, diverse floral and faunal species, habitats, and an adequate supply of good quality water.

The development of an Integrated Watershed Management Plan involves four major tasks:

Development of an understanding of the current watershed features (natural and cultural) and how they function;

Prediction of current and potential future impacts on the natural environment which may result from land use changes and development;

Recommendations for possible ecological restoration and/or enhancement measures which could improve existing watershed features and functions; and

Development of an approach for managing future development in the watershed which includes specific policies for natural heritage features and developable areas.

The benefits of good watershed management include:

Protection of property from flooding and erosion;

Protection of water quality;

Protection of natural areas, green space, and habitats;

Preservation of aesthetic quality.

A number of recent land and resource use activities and applications in the Big Creek watershed have highlighted the difficulty in assessing the watershed in terms of the varied natural resource values and community priorities that exist in the area. This has revealed the need for a watershed plan that can be used to inform decision-making related to a variety of local activities and uses.

In response, this Big Creek Watershed Plan assesses cumulative environmental effects on natural heritage, water quality and water quantity to predict the response of the Big Creek ecosystem to existing and potential human activities. The Plan makes recommendations for appropriate resource management in the watershed to ensure that water resources and related resource features and ecological functions are protected and enhanced to coincide with existing and changing land use and those ecosystem objectives and targets are being met and managed. The watershed plan will not determine land use; however constraints, opportunities, and approaches for input into the land use planning process and municipal Official Plan will be offered. The input of environmental objectives and management recommendations to the land use planning process promotes informed decision-making, resulting in more efficient and effective land use planning.

The Town of Amherstburg, in partnership with the Essex Region Conservation Authority (ERCA), and other agencies (Environment Canada, Ontario Ministry of Agriculture and Food, Ministry of Natural Resources, Ministry of the Environment, and a large private land owner) have collaborated on the preparation a comprehensive and integrated environmental study.

2.1 Goals and Objectives

Ultimately, the goal of the study is to inform planning decisions and provide detailed directions on programs necessary to achieve the long term protection and sustainability of the Big Creek watershed, in keeping with local, Provincial, Federal and other agency policies and initiatives; and one that reflects local community priorities.

Relationship to Other Local and Provincial Legislation, Policy and Initiatives

The Provincial Policy Statement issued under Section 3 of the Planning Act identifies the wise use and management of resources over the long term as a key Provincial interest. To implement the Provincial Policy at the local level, municipalities, in partnership with ERCA and other agencies, ensure that resources in the watershed are managed in a sustainable way to protect essential ecological processes and public health and safety, and to avoid or minimize environmental impacts.

The Town of Amherstburg Official Plan was adopted by Council in 2006. Since that time, changes to Provincial legislation and guideline documents have been released including the revision to the Natural Heritage Reference Manual. The preparation of the watershed plan is intended to make recommendations to guide future policy direction in the Official Plan. The Town of Amherstburg Official Plan provides goals and policies relating to natural heritage protection and creating linkages.

The Big Creek watershed outlets into Lake Erie, with run-off water affecting near-shore water quality within the Great Lakes system. The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem recognizes the clear linkage between tributary and near shore lake water quality. Specifically, Annex 3 Lake and Basin Sustainability of COA envision strengthened local science and information that can be used to enhance Great Lakes sustainability to achieve social, economic and aquatic ecosystem well-being.

The purpose of the Permit to Take Water Program (PTTW) is to manage the taking of water to ensure the fair sharing of water, promote stewardship and prevent unacceptable interference with other uses of water. The Ontario Water Resources Act sets out the legislative requirement to have a permit to take more than 50,000 litres per day. Permits allow for the taking of surface water or from groundwater (aquifer) sources or both depending on the details listed in the permit. The water taking permits within the Big Creek watershed were collected and analyzed as part of the water quantity study.

The Ontario government passed legislation referred to as the "Clean Water Act" in October 2006 to protect drinking water at the source as part of an overall commitment to human health and the environment. The Essex Region Source Water Protection Committee has previously developed the Conceptual Water Budget Report for the Essex Region Source Protection Area (SPA). This report served as a reference for the preparation of the water quantity and quality components of this study. Water budget analysis forms one of the important components in the source water assessment report where water supply and demand are quantified, and water movement within the watershed is understood. A water budget is an understanding and account of the movement of water and the uses of water over time on, through, and below the surface of the earth (Ontario Ministry of Environment (referred to as MOE), 2006).

Community Consultation

Consultation with the public and stakeholders is central in developing a local Watershed Plan. Local residents are partners in the implementation of the plan and need to have a role in the development.

The Big Creek Steering Committee consulted with residents, property owners, and stakeholders throughout the planning process. The input from these consultation activities has been considered by the Committee in developing the Watershed Plan. Public and stakeholder consultation was conducted using the following methods:

Distribution of factsheets, brochures, and pamphlets;

Property specific mailings to landowners within the Big Creek watershed;

Public open houses and information sessions;

Public questionnaire

Review of public comments

Online consultation at www.erca.org;

Public education and information sessions on stewardship practices, grant availability, and legal requirements.

Vision for the Big Creek Watershed

The following vision statement was developed based on the Town's Official Plan, Terms of Reference for the Study and comments received from the public during the development of the Plan:

> "*Big Creek watershed will support a balanced ecosystem with clean, safe water, functioning wetlands, and a diversity of native plants, fish and wildlife. Natural and human heritage features are protected and valued. The residents recognize the health of the watershed as essential to the community as a resource that enhances their quality of life. All stakeholders will participate in stewardship and enhancement of the watershed and continue to protect this resource as a priceless legacy*."

In order to achieve this vision objectives for the Big Creek Watershed Plan include the following objectives which are separated into three sections: Water Quantity, Water Quality and Natural Heritage.

Objectives: Water Quantity

- Complete a water quantity assessment and erosion characterization study for Big Creek Watershed existing conditions with the use of the watershed modeling tools Soil and Water Assessment Tool (SWAT) and Annualized AGricultural Non-Point Source pollution modeling (AnnAGNPS)
- Develop existing condition water budget models for the Big Creek Watershed and Big Creek Marsh for use when developing the water management plan in the next stages of the study
- Investigation of various marsh succession management scenarios, viz., openwater, hemi-marsh and overgrown conditions, during dry, average and wet years under different Lake Erie levels
- Investigation of the effect of variability in precipitation and streamflow conditions on the Big Creek Marsh water budget and marsh succession conditions

Objectives: Water Quality

- Complete a detailed surface water quality study to characterize ambient and long term water quality trends in the watershed as well as identify the sources of various pollutants in the watershed.
- Complement existing water quality data with additional fixed water quality monitoring stations and by completing regular as well as precipitation event-based sampling.

Objectives: Natural Heritage

- Complete a detailed study of the natural heritage features in the watershed utilizing standardized criteria and evaluation protocols.
- Identify significant values and significant impairments of the natural heritage system
- Document the association of identified natural heritage values and hydrological processes.
- Provide recommended actions to mitigate and restore impaired functions.

3.0 About the Big Creek Watershed

Study Area

The Big Creek Watershed is located in the southwestern portion of the Town of Amherstburg, in Essex County bordering on Lake Erie and the Detroit River. This watershed can be considered a sub-watershed to the Lake Erie Watershed. The watershed is located completely within the Carolinian Life Zone, which is recognized as one of the most biologically diverse regions in Canada. This watershed has drainage area of over 7,300 hectares (18,000 acres) and includes parts of the urban core of Amherstburg as well as rural and agricultural lands (Figure 1). Big Creek watershed is linked to the Great Lakes, via Lake Erie. The predominant land use in the watershed is agriculture due to the region's mild climate and excellent growing conditions. The soils within this watershed generally consist of Perth Clay Loam and Brookston Clay. ERCA's Watershed Report Card is developed based on regular water quality monitoring to assess the health of each of the areas' watersheds for future baseline information. Big Creek scored the highest of any watershed in the region for overall surface water quality.

Figure 1 Big Creek Watershed

Land Use History and Settlement

The Big Creek watershed has been a significant area for human cultural heritage for the past 11,000 years. Cultural artifacts reveal that the aboriginal people used the Big Creek watershed for shelter, fishing, hunting and transportation. "It is apparent that the aboriginals knew the forests well, especially in terms of resource use. Hinsdale observed that the Indians had a decided preference for the deciduous forests except in special situations as the maple, beech and oak predominated forests provided more fertile soil and rich abundance of forage for animal life." (Pegg, 1986)

The aboriginal artifacts have provided evidence of the lifestyle and resource use at that time and complete transformation of the watershed that occurred since European settlement. This information is helpful to understand the original natural form of the landscape which was rich with a diversity of flora and fauna, very different from the current conditions. Aboriginal artifacts have identified that 558 plants were used within the Great Lakes for food and utility, beverage, flavoring, medicinal, ceremonial and smoking purposes. The evidence further provides that maple sugar and wild rice may have been the most important plant food in early historical times. The wildlife that existed in early 19th century in Essex County included black bear, lynx, wapiti or American elk, passenger pigeon and beaver. In pioneer times, fishing was an important factor in subsistence and it is noted that there was an abundance of species within all streams. Fruits and berries that were likely stored for winter subsistence by the aboriginals included strawberries, June berries, currants, gooseberries, raspberries, blackberries, cherries, blueberries, plums, thorn apples, and cranberries. Nuts which were also abundant included hazelnuts, beechnut, butternut, hickory nut and acorns.

At the time of European settlement the Essex region, on the whole, exhibited a very rich, diverse landscape completely covered in lush natural features. It has been recorded that trees within forests stood two hundred feet tall; and that the darkness in the forest was such that one could not read a printed page at noon on a sunny day. (Pegg, 1986) "The diverse landscape was seen as a hostile environment to be tamed, as a result a massive effort to clear and develop land for agriculture resulted." Alterations to natural drainage, re-routing of watercourses and clearing of natural features in the Big Creek Watershed since European settlement have resulted in changes to watershed hydrology which has provided the need for this study.

The Town of Amherstburg, which is also located within the watershed, has a rich history dating back to the 1640's when French explorers are known to have paddled past where the Town of Amherstburg now stands. The first European settlement in the Detroit-Windsor area occurred in the year 1701, when the Sieur De Lamothe Cadillac and approximately 100 military and civilian personnel arrived to find Fort Pontchartrain on the Detroit side of the river. European settlement remained largely confined to the Detroit side of the river until 1748, when the Jesuit mission to the Huron Indians was established on the south shore (Windsor), near the foot of the present Huron Church Road and the Ambassador Bridge; this marked the beginnings of Essex County.

The rapid changes to the landscape, occurring over 100 years, with forest clearing and drainage gave little concern to the condition of the natural resources and their ability to withstand the effects of increased development. Within the first hundred years of permanent settlement, the fur trade had eliminated significant numbers of wildlife. Clear cutting of forests to make way for agriculture removed two thirds of the forest habitat in Essex County within a fifty year time period. As well, thousands of acres of wetlands were drained for agriculture. (Pegg, 1986)

It was realized in the latter half of the nineteenth century that too much timber had been wastefully cut; in many cases only to reveal land that was not profitable to farming. Farm and forest were no longer seen as mutually exclusive. Successful agriculture required windbreaks and woodlots and forests to provide shelter and to regulate water supply.

Another condition that influenced settlement, development and agricultural productivity in the watershed was the creation of drainage. Much of the land in Essex County was so flat that it required drainage which did not begin until 1880. This was due, in part, because of its expense and initially there was no recognition for its necessity. The passing of the Drainage Act in 1878 allowed the draining of marshes which were then brought into cultivation. (Pegg, 1986) The result that exists today, is very flat topography, historically covered by wetlands which were drained at the time of European settlement, with extensive largely almost indefinable floodplains requiring an extensive man-made drainage system to support agricultural practice. This has created a challenging situation for flood protection for homes and agricultural lands.

The majority of the Big Creek Wetland located south of County Road 20 was assembled in the 1920's by Mr. W.G. Arthur Reid which shortly thereafter was known as Big Creek Hunting and Fishing Club. Mr. Reid, a conservationist and a sportsman, purchased the bulk of the lands in 1925 to manage the area as a private game preserve. In those years succeeding the World War I (WWI), marshes were given little to no protection and were often considered a liability to good farm land in Malden Township and Essex County. This substantial marsh area has been privately managed through extensive conservation efforts since that time by a small group of environmentally conscientious individuals. In 1958, the provincial government purchased 262 acres in Malden Township to establish a Provincial park (Holiday Beach).

Historical Industry

Major industries located within the watershed include Allied/General Chemical, Honeywell site and Amherstburg quarries. The beginning of the former General Chemical plant commenced in 1900 when the local stone quarries began supplying calcium rich crushed stone to the Solvay Process Company in Delray, Michigan which used it in the production of soda ash. Soda ash is a key chemical used in the production of glass, soap and the bleaching of fabrics and paper. With an abundant supply of limestone and the presence of extensive brine fields near the Canard River, Amherstburg was a logical place to locate a plant to produce soda ash.

In 1917 after acquiring lands near Amherstburg and River Canard, Brunner Mond of Great Britain announced that it would build a new plant in Amherstburg to produce soda ash. In 1936 the plant started to produce calcium chloride in addition to soda ash. In 1958 Allied Chemical acquired the operation which produced over 300,000 tons of soda ash annually. Subsequent improvements were made to produce hydrofluoric acid.

In 1989 the soda ash and calcium chloride operations were sold by Allied Chemical's corporate successor, Honeywell, to General Chemical. Honeywell retained the hydrofluoric acid facilities together with part of the lands. At that time the operations employed 490 people and produced 475,000 tons of soda ash and 400,000 tons of calcium chloride annually from one million tons of salt obtained from the brine fields and 650,000 tons of 90% calcium rich limestone produced from its open pit quarry.

General Chemical discontinued soda ash production at Amherstburg in 2001 and entered bankruptcy in 2005 at which time the production of calcium chloride was shut down. The property contains five above ground brine and calcium chloride storage lagoons, storage tanks for holding heavy oil and a 176 ac. Soda Ash Settling Basin. The Province of Ontario reached a settlement with the U.S. parent corporation of General Chemical in 2009 to fund a cleanup of the site. (Canwest media works publications, (http://www.canada.com/windsorstar/story.html?id=16f4a790-411f-4a0e-80fe-1ebac89b5f29)

The historical major diversions of headwater areas out of the Big Creek watershed resulted in the loss of half of the original watershed area. The two major, historical diversions are associated with the Long Marsh Drain. The area of the watershed that now drains to the Richmond Drain and upper portions of the Long Marsh Drain used to flow into the present day Big Creek watershed but were rerouted away many decades ago. The upstream (southwestern) portions of the Richmond Drain (about 3,200 ha) once drained into the Long Marsh Drain but are now rerouted into Cedar Creek (Figure 2). The upstream portion of the Long Marsh Drain (approximately 4,800 ha) was also connected to the lower portion of the present day Long Marsh Drain.

As a result of these two changes, the Big Creek Watershed drainage area was substantially reduced by about 8,000 ha (over half of the current watershed), which in turn has affected the drainage characteristics and hydrology of the watershed. This is of particular significance from the low-flow point of view. Limited field surveys and anecdotal information has revealed that the Richmond Drain generally carries a substantially higher fraction of the base flow throughout the year when compared to the present data Big Creek Watershed. As well, the historical disconnection of one of the Big Creek tributaries on the southwestern portion of the watershed from the Detroit River has further impacted the lack of water quantity. This number of historical diversions is an unusual situation in the region which has very substantially affected the natural hydrology and flow conditions in the watershed.

Figure 2 Big Creek Watershed showing historical watercourse diversions

Existing Land Use

The Big Creek Watershed's land use is extensively agricultural at about 70% of the watershed area. The primary crops grown on these agricultural lands are soybeans, corn and winter wheat. The urban settlement in the watershed includes a part of the Town of Amherstburg urban core and some small patches of development outside the area. The total developed (pervious and impervious) area is 5% of the watershed. The Essex Region Natural Heritage System Strategy has recently provided that 20.5% of the watershed is natural and 79.5% contains anthropogenic land uses. The natural areas are divided between terrestrial habitat at 6.21% and wetland habitat at 14.29%. This is well above the regional average of 2.5% wetland and 5% tree cover. Urban areas are concentrated in the northwest portion of the watershed and cover about 5% of the total watershed. The watershed has good transportation networks, with about 3.2% of the area occupied by transportation paths. A significant portion of the watershed contains open water, generally higher than many of the other watersheds in Essex region.

The Big Creek watershed drains over 7,000 hectares (17,000 acres) including parts of the urban core of Amherstburg as well as rural and agricultural lands to the south. The flat, clay plain of Essex County has poor natural drainage which has resulted in more kilometers of municipal and agricultural drains compared with any other county in Ontario. (Corkum, 2010) The population density is considered low identifying <150 people per km2. The density is consistent with rural municipalities of Essex County.

Table 1 Land Use Distribution in the Big Creek Watershed

Land Use Type	Area (ha)	% Area of Watershed
Rural/agriculture	5,194	71.1
Wetland	1,040	14.2
Wooded area	230	3.2
Transportation	230	3.2
Built-up area (impervious)	223	3.1
Hedge rows	143	2.0
Built-up area (pervious)	107	1.5
Water body	91	1.2
Extraction (aggregate extraction and quarry sites)	44	0.6

Climate

The climate of the Big Creek Watershed is characterized as warm, with long summers and cool short winters. The Essex region which is referred to as the "Sun Parlour of Canada" receives hot air from the south during the summer and the cooler air in the winter as a result of cold dry arctic air. This area is located on one of the major storm tracks of the continent and thus experiences continuous variations in weather. Due to its geographical location, this region receives more precipitation than the Prairie Provinces and less than the east coast of Canada. The presence of Lake Erie affects the temperatures along the southern shore of the Essex region.

Soils and Geology

The soils of the Big Creek Watershed resulted from the deposition of sediment and outwash materials in the glacial lakes over an extended period of time. The soils of the region are classified into several soil series, which are groups of soils formed from similar parent materials that have similar profiles but vary within a narrow range of texture, particularly with the surface soil. On the basis of texture, the soils within a soil series were further divided into soil types. The below figure depicts the different types of soils in the Big Creek Watershed. The majority of the watershed is covered by clayey soils with Perth clay loam soil as a dominant soil type covering much of the southeast portion of the watershed. The area covered by each soil type is presented in Table 2. The watershed is dominated by four soil types over 93% of the area. The Perth soil series consists of over 65% of the area, which has fair to poor natural drainage characteristics. The Brookston soil series covers about 16% of the watershed area, which is characterized with poor natural drainage. As a result, this watershed experiences poor natural drainage overall.

Table 2 Soil Type Area Coverage

Soil Type	Area Covered	
	(ha)	% Area of the Watershed
Perth clay	3,213	44%
Perth clay loam	1,584	21.7%
Brookston clay	1,136	15.5%
Marsh	891	12.2%
Bottom land	253	3.5%
Burford loam - Shallow phase	96	1.3%

Brookston Clay Loam	67	0.9%
Brookston clay sand spot phase	48	0.7%
Eastport Sand	9	0.1%
Farmington Loam	7	0.1%

Soils of the Big Creek Watershed (Richards et al., 1949)

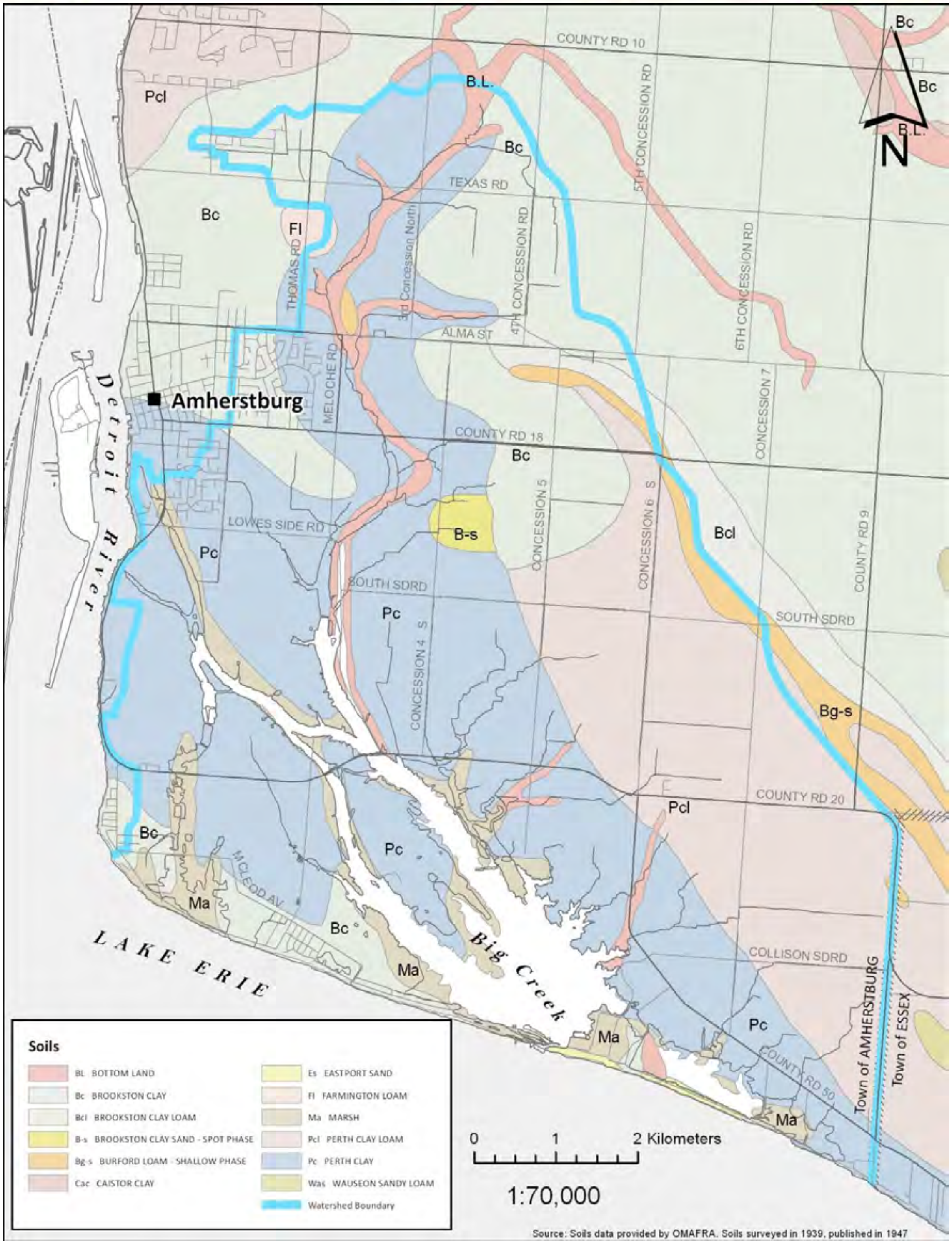


Figure 3 Soils of the Big Creek Watershed

Ground Water and Baseflow

Conservation Authorities throughout Ontario, in partnership with the Provincial Ministry of Environment, implemented a network of monitoring wells to measure water levels, and water quality, on a long term basis. The simulated groundwater flow is relatively low compared to the other hydrologic components, which could be due a variety of reasons such major historical watercourse diversions and the existence of extensive tile drainage networks within the Big Creek Watershed.

Surface Water

A detailed surface water quality analysis has been undertaken in order to characterize ambient and long term water quality trends in the watershed as well as the sources of various pollutants in that watershed. From 1964 to 1996 surface water quality in Big Creek was monitored at two stations through the Provincial Water Quality Monitoring Network (PWQMN) program. At present, there are two water quality monitoring stations, which are monitored through ERCA's region-wide surface water quality monitoring program.

Through expanded water quality sampling for this study a clear understanding of ambient water quality and event-based pollutant loadings from various sources to the watershed will be achieved. This information can then be used to establish water quality targets for watershed sub-basins, with associated measurable actions to achieve those targets, through the watershed plan itself.

The major components of the hydrologic cycle include surface water flow (yield), precipitation, groundwater flow, and evapotranspiration (USGS, 1999). The Wetland Reserve Program has provided technical notes which support the hydrologic cycle components adding that precipitation is crucial in the water budget creating an inflow directly through rain occurring within the watershed's physical limits and as a source of stream flow generation.

Natural Heritage

The Big Creek watershed contains 19% natural area coverage, the highest natural area cover of any watershed in the Essex region. The Big Creek marsh wetland at the mouth of the watershed contains a 900 ha (2500 acre) Provincially Significant Wetland. The marsh PSW is also a provincially identified Area of Natural and Scientific Interest (ANSI), Environmentally Significant Area (ESA) and a globally important bird area (IBA).

4.0 Water Quantity

4.1 Introduction

The historical major diversions of headwater areas out of the Big Creek watershed has resulted in the loss of about half of the original watershed area. One major and historical diversion is associated with the Long Marsh Drain, as well as the disconnection of one of the Big Creek tributaries on the southwestern portion of the watershed from the Detroit River. The number of historical diversions that have occurred within one watershed is an unusual situation in the region, which has substantially affected the natural hydrology and flow conditions of this watershed.

Various local stakeholders of the Big Creek Watershed have embarked on the development of a watershed plan as a proactive approach to planning and stewardship activities. This report provides the existing water quantity conditions of the Big Creek Watershed, including watershed hydrology and wetland water balance. An erosion characterization was also undertaken to provide estimates of non-point source pollutant loadings.

The purpose of the water quantity study is to understand the hydrologic impacts associated with the watershed to a level of detail that the need and recommendations for protecting and enhancing water quantity levels throughout the watershed can be understood. This information, along with other reports on natural heritage and water quality, will be used for the development of the Big Creek Watershed Plan.

4.2 Methodology

The quantification of water resources in the watershed is of paramount importance in developing the watershed plan. In order to undertake a comprehensive water quantity analysis of this watershed, many tools and methods have been utilized. Discussions with municipal and Conservation Authority administration, as well as residents have provided a great deal of insight regarding observations in changes to the drainage and hydrology throughout the watershed. A water budget was prepared as one of the major components of the water quantity study. This is a mathematical model assessing and balancing water entering, leaving and being stored in a system. In order to develop hydrologic modeling tools, physical data requirements include: topography, soils, land use, and drainage information. As well, climate data including daily precipitation, maximum and minimum temperature, wind speed, relative humidity and solar radiation were necessary models inputs.

A Geographical Information System (GIS) based continuous simulation model called the Soil and Water Assessment Tool (SWAT) was used to develop an understanding of the water budget components of the Big Creek Watershed. A spreadsheet-based model was developed to provide water budget component estimates of the Big Creek watershed, including the significant inflows and outflows.

There is no historical streamflow data available for Big Creek Watershed to calibrate and validate the model, however short term streamflow monitoring was performed for model testing. Results from a recent modeling exercise of the Canard River Watershed were also used as a model check based on similar spatial and temporal characteristics. The SWAT model was used to describe the hydrologic components of the watershed, most of which contributes to the Big Creek Marsh. A total of 40 subwatersheds were delineated within the study area with information utilized for a period of 20 years (1990 to 2009).

In order to characterize the watershed's contributing sediment and nutrient loadings, a continuous agricultural non-point source pollution simulation model, AnnAGNPS, was used. Tile drainage throughout the watershed is extensive due to the high level of agricultural land use activities and poor natural soil drainage to improve soil productivity. Topographical data in the form of a Digital Elevation Model (DEM) is a fundamental input of spatially distribution models including SWAT and AnnAGNPS.

4.3 SWAT Model Results

The SWAT model simulated hydrologic water budget results from 1990 to 2009 which have been presented annually, seasonally and in monthly time scales.

The annual model results show that evaportanspiration (ET) is the largest hydrologic component at a depth of 601 mm, which is 65% of the average annual precipitation of 907 mm. The other hydrologic components include surface runoff (water yield), tile drainage flow and groundwater flow at 224 mm, 69 mm and 14 mm, respectively (25%, 8% and 2%, respectively). The simulated groundwater flow is relatively low compared to the other hydrologic components, which could be due to a variety of reasons such as major historical watercourse diversions and the existence of tile drainage networks within the Big Creek Watershed. The model results identified that the highest levels of ET are occurring in the northern and southwestern portion of the watershed.

Average seasonal analysis indicates that precipitation is higher than ET and water yield combined in the winter, spring and fall. During the summer period, precipitation is less than ET and water yield combined, which indicates soil moisture generally depletes during the summer season. This depletion is normally replenished during the following fall season with the higher relative precipitation.

Average monthly precipitation for the watershed study varied from 59 mm to 91 mm, with higher precipitations of above 80 mm during the months of April, May, August and September. The lowest average precipitation of 59 mm occurs in February. Higher ET rates are found in June, July and August, with the July average the maximum value at 121 mm. Lower average ET values of below 20 mm are found in December, January and February. Higher surface runoff volumes above 35 mm are found in February and March, while lower surface runoff volumes ranging between 6 mm and 11 mm are found during the months of July to November.

Monthly average streamflow analysis shows that streamflow varied between 2.5 m3/s and 3.1 m3/s as high values during some years. A number of streamflow values were also found to be less than 0.01 m3/s over the study period, which indicates that this watershed frequently experiences very low flow conditions in certain years. The lowest monthly flow occurred in the year 2005. These results, along with anecdotal observations, indicate that flow conditions in Big Creek are among the most stressed of

Essex Region watersheds. This is likely due, at least in part, to the historical major diversions of headwater areas out of the Big Creek Watershed.

4.4 Big Creek Marsh Model Results

Big Creek Marsh is a riparian wetland in Essex County and is primarily fed by streamflow from the greater Big Creek Watershed. The marsh is approximately 682 hectares in area and is located east of the Detroit River and north of Lake Erie. The marsh was investigated in detail using a spreadsheet for water budget analysis with a daily time step. The historical information related to the marsh was selected for a 40 year period from 1969 to 2008. The Big Creek Marsh is large and shallow, and experiences significant water losses through ET as a result. The water levels of the wetland have been managed to some degree since 1909, using a system of pumps, dykes and a control dam.

Water levels in the marsh have the ability to be managed, which could include targets as approved in a recent management plan associated with a Ministry of the Environment (MOE) Permit to Take Water (PTTW). The goal of this component of the study was to develop a model that would adequately simulate the marsh operations and reactions to streamflow and climatic changes in order to provide suggestions and recommendations to property owners toward a future management plan.

For Big Creek Marsh water budget, inflow and outflow components may include many different components during specific periods of time. The inflow components considered include precipitation, streamflow from the upstream watershed, seepage from Lake Erie into the marsh through the beach ridge along the shore, inflow water pumping from Lake Erie to achieve the desired water level, and flow overtopping the control dam structure from Lake Erie. Outflow components considered for the water budget includes ET, seepage flow to Lake Erie, outflow pumping of the marsh to Lake Erie, outflow to Lake Erie from the control gate, and flow overtopping the control dam structure to Lake Erie. Groundwater inflow and outflow sources excluding Lake Erie are assumed to be zero.

The water budget was developed using 40 years of data, some of which is recorded and some of which is from anecdotal information and observations. The operation of this wetland over this period of time has been split into three operation periods, including the historic management period (1969 to 1984), the carp fishery period (1985 to 1999) and the current management period (2000 to 2008). Though there generally is a lack of information about the specific operations over all three management periods, there is some recorded information available from 2006 to 2008 and anecdotal information available for other years.

During the historic management period, anecdotal information suggests that the operators attempted to manage the wetland in a similar fashion to the current management period, but were limited to the resources available at that time to maintain the infrastructure. For the carp fishery period, the water levels were maintained as high as possible according to anecdotal information, to maximize the carp fishery productivity. For this time period, water levels were held through various means including soil reinforcement of the structure and there was limited to no outflow pumping. The current management period has an assumed marsh operation managed according to a specific management plan as provided to the MOE as part of a 2007 PTTW application. From this application, three potential annual water level operation plans were submitted: Overgrown, hemi and open water. These three operation plans have varied target water levels at different times of the year, and generally consist of a high, medium and low water level operation. The main tools available for wetland operators include the outflow gate and in and outflow pumping.

Since very little recorded data pertaining to the wetland is available, model calibration and validation is not possible. However, to ensure the marsh components are being estimated in a reasonably accurate way, the model was tested against a series of years with some partial information. The drought conditions experienced in the entire watershed in 2005 is a recent extreme event that ERCA staff has a great deal of anecdotal information about, while the MOE PTTW database contains inflow pumping data for the years 2006 to 2008. Comparisons with the model to these test years show that the model development is acceptable. Another model check was performed using sensitivity analysis, which also indicated an acceptable model.

The results for the historic management period shows that the majority of the marsh water level varied between 174.30 m and 175.20 m, with drier periods (water level below 174.30 m) occurring in 7 years (1969, 1970, 1971, 1977, 1978, 1979 and 1982). The overall period water level average is 174.66 m, with an overall minimum and maximum value of 173.90 m and 175.30 m, respectively. In terms of annual average water budget component values, the main inflow components are streamflow (74%), precipitation (23%), and the main outflow components are gate outflow (49%), overflow over the gate (26%) and ET (24%).

The model results for the carp fishery period indicates that the water levels remained higher, primarily varying between 174.80 m and 175.20 m. There were brief dry periods with water levels below 174.80 m during the 5 years of 1988, 1991, 1996, 1998 and 1999, and wetter periods with water levels above 175.20 m during the 6 years of 1985, 1986, 1989, 1990, 1993, 1995, 1998 and 1999. It has also been noted that there is some overlap of years with dry and wet periods. The overall period average water level is 174.85 m, with an overall minimum and maximum value of 174.20 m and 175.50 m, respectively. In terms of annual average water budget component values, the main inflow components are streamflow (72%), precipitation (21%), and the main outflow components are overflow over the gate (76%) and ET (23%).

The model for the current management period assumed that the hemi (medium) operation plan was generally implemented for most years as an overall average operation. The water level tends to vary between 174.10 m and 174.80 m, with an overall period average water level of 174.40 m. In terms of annual average water budget component values, the main inflow components are streamflow (73%), precipitation (22%), and the main outflow components are gate outflow (73%) and ET (24%).

When considering the entire study period, the two largest inputs into the marsh are streamflow (between 72% and 74%) and precipitation (between 21% and 23%), which indicates that the largest inputs affecting this wetland are linked to the natural hydrologic cycle. The higher outputs largely depend on the management period, as gate outflow is the largest parameter for the historic and current management period (49% and 74%, respectively), however this tool is not available for the carp fishery period. The most common output parameter among all operation periods is ET, which varies between 23% and 24%.

The connection between Lake Erie and the Big Creek Marsh was also investigated. Over the 40 year period studied as defined previously, the marsh water levels were higher than the lake water level the majority of the time (93%). This is further confirmed through aerial photograph research during high and low lake water periods as a comparison of marsh health with lake levels for that specific period. It was also determined that there is a correlation between higher marsh water levels and lake water levels. There are also indications that during lower lake water levels, the wetland would experience a natural drawdown period if not artificially maintained with the outlet control gate and dyke system.

Although the optimal operation of the private dam and portable pumping system may be able to sufficiently augment the water levels in the marsh, it may not be realistic to expect that this will always be feasible during prolonged and/or extreme dry periods in the future when there is little or no inflow from the upstream watershed, combined with substantial loss of water due to ET. Another potential complicating factor is climate change, which may result in more extreme weather events and climate variability in the future. It is also important to note that artificially maintained water levels in the marsh do not extend upstream to the middle and upper reaches of the watershed due to historical diversions at the headwaters. These upstream reaches will continue to be highly stressed during drought conditions. Due to major historical diversions of flow out of the headwaters, the natural flow conditions have been highly impacted to a much greater degree than other watercourses in the region. For all of these reasons, serious consideration will likely be given to the feasibility of introducing flows to the upper or middle reaches of Big Creek.

4.5 AnnAGNPS Model Results

The Annualized Agricultural Non-point Source (AnnAGNPS) is a computer model which was utilized to simulate the Big Creek Watershed's sediment, nitrogen and phosphorus non-point source loading results at a daily time step. The model is able to assess impacts of land use alternatives because it can estimate both point and non-point source pollutant loadings on a watershed scale. The watershed was divided into a total of 660 cells over a study period of 20 years (1990 to 2009). Since there is a lack of data available for validation and calibration of this model, hydrologic parameters were compared with the SWAT model to ensure the model development was acceptable. The model can be used to examine current conditions in a watershed, to compare effects of different conservation alternatives, to evaluate results for implementation of best management practices (BMPs) and to analyze risks and cost/benefits within a watershed.

Sediment loading results shows that material eroded three soil types, including clay (49%), silt (42%) and sand (9%). Clay, as the largest contributor to sediment loading, is to be expected as the watershed is composed primarily of clayey soils and the deposition rate of clay is the slowest. The total average watershed sediment yield is 0.974 Mg/ha/yr, with higher sediment erosion contributions from the north-west and south-east regions of the Big Creek Watershed. The maximum and minimum modelled daily flows are 2,153 Mg/day and 0 Mg/day, respectively, with an average of 8.3 Mg/day. The months of April, May and June have the highest average monthly sediment yield rates, which is likely caused by spring runoff events.

For nitrogen, the average annual yield for the watershed is approximately 17.1 kg/ha/yr, with a minimum cell value of 0 kg/ha/yr and maximum cell value of 60 kg/ha/yr, most of which comes from the south-east. The months of March, April and May have the highest monthly average total nitrogen yield.

Phosphorus is not as mobile as nitrogen, but is strongly absorbed by the soil. Phosphorus that is absorbed by sediment particles may be conveyed in overland flow. The average annual phosphorus yield for the entire watershed is 11.4 kg/ha/yr, with a minimum cell value of 0 kg/ha/yr and maximum cell value of 81 kg/ha/yr, most of which comes from the south-east. The months of April, May and June have the highest monthly average total phosphorus yield.

The findings of the Big Creek Watershed Plan have identified the conditions present during the modelled years. This time step however does not include extreme historic lows of Lake Erie and cannot model the conditions that may have been present with a watershed that at one point in time was three times larger than the current modelled watershed. The uncertainty with climate variability dictates the need to have consideration for extreme caution in managing the water resources available to the Big Creek watershed. The historic methodologies of capturing and directing all storm flows and then out letting as efficiently as possible may well be harmful to a waterway that is in a deficit position relative to water budget. Future planning processes will need to respond to the impacts of climate change and ensure that planning models include considerations for managing or supplementing the watershed inputs available to the system with a goal being to balance the current water budget model.

5.0 Water Quality Study

5.1 Introduction

The quality and health of the Big Creek is a fundamental aspect of a healthy watershed and the health of communities in the watershed. A watershed-based approach to manage natural resources is vital to the protection and sustenance of a healthy watershed. The Town of Amherstburg in partnership with the Ontario Ministry of the Environment (MOE), the Essex Region Conservation Authority (ERCA), and a group of private hunt clubs from the watershed, initiated the Big Creek Watershed Plan. This Plan aims to affirm and/or identify and assess natural resources in the Big Creek watershed, and to recommend appropriate strategies for the protection or management of the varied natural resource values and community priorities that exist in the area. Three key watershed-based studies inform the Plan. These are the Natural Heritage Study, the Water Quantity Report and the Water Quality Study. The Water Quality Study methodology and results are summarized below.

5.3 Methodology

The surface water quality monitoring study included two main components. Firstly, historical and long term water quality data in the Big Creek watershed was analyzed to determine if any long term significant trends exist in the watershed. Data from 1964 to 1970 and 1982 to 1996 (at 1 site) through a provincial surface water monitoring program, as well as a data from 1989 to 1990 (47 sites) through a provincial rural beaches strategy program, was analyzed.

Secondly, the assessment of current (2008-2009) water quality conditions was undertaken by conducting a comprehensive surface water monitoring program during 2008 and 2009. This involved water quality sampling in the Big Creek watershed at 2 sites that existed in 2008-2009 as part of the Essex Region Conservation Authority monitoring program, as well as 8 additional sites. Samples were taken along streams, at the marsh and nearshore during regular and wet weather. Data for various parameters, as described below, were analyzed in both components of the study to evaluate long term and current water quality. The study also included a quantitative estimation of loadings of particular pollutants from different catchments within the watershed.

5.4 Evaluation Criteria

The water quality parameter data was evaluated mainly using benchmarks for the protection of aquatic life and ecosystem health. These benchmarks are the Provincial Water Quality Objectives (PWQO) published by the Ministry of Environment (MOE), the Canadian Environmental Quality Guidelines (CEQG) published by the Canadian Council of Ministries of the Environment (CCME), and a recreational water use standard for bacteria. The parameters reviewed include nutrients (nitrates and phosphorus), E. coli, chloride, pH, metals, and others. Benthic invertebrate data was analyzed using the Benthic Index of Biotic Integrity (B-IBI. A simple fecal coliform/fecal streptococcus ratio method was employed to understand the potential sources of microbial contamination at various sites in the Big Creek watershed.

5.5 Results

Long Term Water Quality

The surface water quality data collected at the Provincial water quality monitoring site in the Big Creek watershed showed high levels of total phosphorus and chloride. Almost all of the samples collected during 1964 to 1996 exceeded the PWQO for total phosphorus, while annual mean chloride concentrations during 1985 to 1995 exceeded the benchmark of 250 mg/L in all years, except 1986 and 1987.

Nitrate and total suspended solids (TSS) levels were found to be significantly high and increased between 1980 and 1994. E. coli was not monitored at this site during this period however other pathogens, fecal coliform and total coliform, were very high indicating contamination of surface water by human origin waste.

The Essex Conservation Rural Beach Program (1989-1990) study found widespread pollution of bacteria and phosphorus throughout the watershed. Nearly all the samples collected during this period exceeded the MOE guidelines for E. coli and total phosphorus. Very high counts of Pseudomonas at all the sites indicated widespread human fecal contamination. The study suggested that soil erosion might be the major source of phosphorus contamination.

Current Water Quality

Although there has been a reduction by approximately 30% in average total phosphorus concentrations since the 1960s, current levels remain significantly above the benchmark PWQO limit of 0.03 mg/L. Also a slight increase in current total phosphorus data was observed from upstream stations to the downstream stations. The total phosphorus concentrations observed in the marsh and at the nearshore (Lake Erie) sites were also above the benchmark but significantly lower than those found at the tributary sites. In general, the total phosphorus concentrations in the Big Creek watershed are typical of highly agricultural landscape of the Southwestern Ontario. Potential sources may include run-off from fertilized agricultural lands within the watershed and urban inputs from the Town of Amherstburg.

The nitrate levels in most of the samples were below the CEQG limit of 2.93 mg/L. The majority of the nitrate in the Big Creek watershed originates in the northeast region of the watershed. The current levels of nitrate in the watershed appear to be similar to historical levels. Nitrate levels were found to be well below the benchmark at all four sites in the marsh and nearshore area.

In general, chloride concentrations in the Big Creek watershed tend to be high compared to typical chloride concentrations observed in small streams in Essex Region. Chloride is typically indicative of road salt in urban runoff. The current levels of chloride appear to be lower than historical levels. The majority of the chloride in the Big Creek watershed originates from the 3 headwater sites, all of which have relatively high urban land drainage area. The lower concentrations in the downstream sites could be attributed to dilution. An unusually high chloride spike was observed in 2009 at a site on Big Creek at Alma Street, just downstream of the soda ash basin. More investigation on this issue is warranted.

Chloride levels in the marsh and at the nearshore sampling were normal and well below the benchmark value of 250 mg/L.

The E. coli levels tend to be higher than the recreational guideline limit of 100 CFU/100mL at the tributary sites in the Big Creek watershed. No significant difference was found between wet weather and regular weather E. coli counts. The E. coli counts in the samples collected in the marsh and nearshore area are well below the benchmark. E. coli is considered to be an indicator of fecal contamination.

Heavy metals analyzed include arsenic, cadmium, chromium, iron, lead and zinc. There are high levels of iron in all of the Big Creek watershed samples, exceeding the PWQO of 0.3 mg/L. Copper and zinc levels exceeded the PWQO criteria at the site BC-3 which is just downstream of the urban land in the Big Creek watershed. The majority of water samples in Lake Erie and the marsh showed metals below the detectable limits, with just a few exceptions for the marsh inlet samples.

Measured pesticides included atrazine, 2.4-D, metolachlor, and glyphosate. Pesticide results revealed all the pesticides below detectable limits, except that atrazine and glyphosate were found in low concentrations at all the tributary sites. The site BC-3 showed an exceedance of glyphosate. The majority of water samples in Lake Erie and the marsh showed pesticides below the detectable limits, with just a few exceptions for the marsh inlet samples.

The benthic community is graded as very poor to good, based on the Benthic Index of Biotic Integrity (B-IBI) scores obtained for all seven monitoring sites in the Big Creek watershed. The site BC-N, which is immediately downstream of a highly urbanized area of the watershed, showed very poor benthic community, while the benthic community observed in the marsh was of good quality.

Fecal coliform/fecal streptococcus (FC/FS) ratios for all the monitoring sites in the Big Creek watershed were reviewed. The results indicated bacterial contamination due to only human fecal sources at site BC-3, the site just downstream of the urban land in the Big Creek watershed. These results do not confirm absence of human fecal contamination at other sites in the watershed. More advanced E. coli source tracking methods need to be employed in future focusing mainly in the drainage area of site BC-3.

The Water Quantity Study Report, which is one of three Technical Studies that form the background for the Big Creek Watershed Management Plan, presents the results of sediment and nutrient loading estimations using the Annualized Agricultural Non Point Source Pollution (AnnAGNPS) model. The modelled average daily mass flow of total sediment from the Big Creek Watershed is 8.3 mg/day. The months of April through June have the highest average monthly sediment yield rates, which is likely caused by spring runoff events. The average daily mass flow of nitrogen and phosphorus from the Big Creek Watershed are 207 kg/day and 112 kg/day, respectively. The areas with the lowest average annual phosphorus and nitrogen yields in the watershed had land use types of forest and open water. Refer to the Water Quantity Study Report for more details on the sediment and nutrient loading estimations.

Based on the results of the water quality monitoring study, measures such as efficient private septic systems, proper road salt management and implementation of focused agricultural best management practices such as buffer strips, conservation tillage and soil erosion control structures (e.g. rock chutes, header tile retrofits) are suggested in order to improve and protect the water quality conditions in the Big Creek watershed.

6.0 Natural Heritage

6.1 Methodology

Based on extensive public consultation, landowner permission was obtained and a total of 1318.7 hectares (3258.5 acres) of natural area within the Big Creek watershed were inventoried during the 2009 field season, as part of the study. In the spring of 2009, field biologists undertook the initial biological inventories of each of the sites which included the determination of the spring flora and an examination of standing water for amphibian breeding. Throughout the remainder of the 2009 field season, the team of specialists undertook additional faunal surveys, including wildlife and amphibian inventories; completed the botanical inventories to document summer and autumn flowering species and woody vegetation (trees and shrubs); as well as complete vegetation community mapping. A complete floral and faunal inventory was produced for each of the sites documenting all rare species. The locations of significant species and any Species at Risk were recorded utilizing a hand-held Global Positioning System (GPS).

6.2 Evaluation Criteria

The following ten criteria were utilized by the study team, in order to document and evaluate a site's natural heritage significance. The five criteria of the left column below are based directly on the significant natural heritage features defined by the Provincial Policy Statement (PPS).

Significant Wetland
Significant Habitat of Endangered/Threatened Species
Significant Woodland
Significant Wildlife Habitat
Significant Valleyland

Ecological Function
Diversity
Significant Species
Significant Communities
Condition

6.3 Results

Soils

Upland soils within the watershed are mostly classified as Perth Clay (Pc), with some areas of Brookston Clay (Bc) in the southwest and northern portions of the watershed. In addition, Perth Clay Loam (Pcl) soils occur on the eastern side of the watershed and small areas of Burford Loam Shallow Phase (Bg-s) and Farmington Loam (Fl) occur in the northern portions of the watershed. The beach is classified as Eastport Sand (Es) and soils classified as Bottom Land (B.L.) occur mainly along the east branch of Big Creek. Wetland soils are classified as Marsh (Ma) and occur all along the Big Creek and Mans Marsh wetland areas.

Natural Heritage Significance

Lands within the watershed have been identified as within the Big Creek Marsh Provincially Significant Wetland (PSW), as a result of evaluation and mapping conducted by staff of the Ontario Ministry of Natural Resources (OMNR) during the 2009 field season. The watershed contains the Big Creek Marsh

life science Area of Natural and Scientific Interest (ANSI) as identified by the Ontario Ministry of Natural Resources (OMNR), signifying one of the best examples of shoreline marsh and associated wetland in the Province of Ontario. The watershed contains lands which are within the boundary of the Big Creek Significant Valleyland as mapped by the Essex Region Conservation Authority (ERCA). In addition, Big Creek has been identified as an Environmentally Significant Area (ESA) by ERCA, a Carolinian Canada Site and an Important Bird Area.

Ecological Function

The extensive wetland area within the watershed performs the ecological function of hydrological flow, water retention and purification; receiving water from upstream, and purifying it within the wetlands before flowing out into Lake Erie or filtering through the barrier beach. The main wetland area of the Big Creek marsh basin is the primary location where sediments settle out of suspension and nutrients and bacteria are metabolized by the extensive submergent aquatic wetland plant community. In addition, many portions of the watershed provide extensive linkage between the natural features at the mouth of Big Creek, along the Lake Erie shoreline, on Knapp's Island, and north of County Road 20.

Vegetation

The watershed exhibits extremely high diversity with respect to the number and types of vegetation communities, containing 115 vegetation types (ecoelements) in 22 Community Series as identified and mapped according to the Ecological Land Classification (ELC) System for Southern Ontario. Vegetation community composition is 63% wetland/aquatic and 37% terrestrial. The uplands support 53 woody and 13 herbaceous plant communities. The wetlands support 35 herbaceous and 14 woody plant communities. A total of 10 significant communities ranked as provincially rare occupy almost one quarter of the entire watershed area surveyed. The most significant of these communities is a 214 hectare (529 acre) American Lotus Floating-leaved Shallow Aquatic vegetation community which occupies over 16% of the watershed area surveyed. This may indeed be the largest population of this provincially rare plant and vegetation community in Ontario. The Big Creek watershed also contains the Region's largest (and perhaps only) stand of Wild Rice marsh, a community which requires fluctuating water levels in order to thrive.

Significant Woodland

The Big Creek watershed contains woodlands which fulfill the Significant Woodland criterion, based on the following criteria:

Two hectares in size or larger,

presence of interior forest habitat more than 100 m from the edge,

greater than 0.5 hectares in size located within 30 metres of fish habitat likely receiving ecological benefit, and/or greater than 0.5 hectares in size consisting of a vegetation community with a provincial ranking of S1, S2 or S3 (as ranked by the Ontario Ministry of Natural Resources' (OMNR) Natural Heritage Information Centre (NHIC)).

Fifty-two (51) different wooded vegetation communities were identified throughout the watershed, with four (4) of these communities currently ranked as provincially rare.

Floral Species

Floristically, the watershed's flora has a mean Coefficient of Conservatism (CC) of 5.10 and a Floristic Quality Index (FQI) value of 104.23. This indicates that the watershed's flora is relatively intact with high floristic quality, an extremely rare condition representing a significant component of Ontario's native biodiversity and natural landscapes. The Wetness Index for the site, calculated from the mean Coefficient of Wetness (CW) of all native taxa recorded from the site inventory, is -0.36 indicating that the site has a predominance of wetland species.

A total of 562 plant species were identified from 4458 observations recorded during the botanical inventory for the watershed. A total of 56 significant floral species were documented, 5 of which are listed as Species at Risk. These include Red Mulberry (*Morus rubra*) [Endangered], Willow Aster (*Aster praealtus var. praealtus*) [Threatened], Kentucky Coffee-tree (*Gymnocladus dioicus*) [Threatened], Hop Tree (*Ptelea trifoliata*) [Threatened], and Golden Seal (*Hydrastis canadensis*) [Threatened] species.

Wildlife

A total of 259 animal species were identified from 2562 observations recorded during the faunal inventory for the watershed. A total of 159 species of birds, 16 species of mammals, 10 species of reptiles, 6 species of amphibians, 38 species of butterflies, and 30 species of Odonata (dragonflies and damselflies) were documented within the Big Creek watershed during the 2009 faunal surveys. A total of 66 significant faunal species were documented, 9 of which are listed as Species at Risk. These include King Rail (*Rallus elegans*) [Endangered], Prothonotary Warbler (*Protonotaria citrea*) [Endangered], Eastern Foxsnake (*Pantherophis gloydi*) [Endangered], Least Bittern (*Ixobrychus exilis*) [Threatened], Blanding's Turtle (*Emydoidea blandingii*) [Threatened], Butler's Gartersnake (*Thamnophis butleri*) [Threatened], Peregrine Falcon (*Falco peregrinus*) [Threatened], Chimney Swift (*Chaetura pelagica*) [Threatened], and Stinkpot or Eastern Musk Turtle (*Sternotherus odoratus*) [Threatened].

Significant Wildlife Habitat

The Big Creek watershed contains colonial bird nesting sites of Least Bittern, Forster's Tern, Black Tern, Marsh wren, Red-winged Blackbird and Common Grackle. The open water wetlands are significant as a waterfowl stopover and staging area, while the diverse upland areas within the watershed provide landbird migratory stopover areas as well as stopover habitat for the Monarch butterfly. Some areas within the watershed provide Turkey Vulture summer roosting areas as well as suitable areas of reptile hibernacula for the following species: Eastern Foxsnake, Butler's Gartersnake, Northern Watersnake, DeKay's Brownsnake, Snapping Turtle, Midland Painted Turtle, Blanding's Turtle, Common Map Turtle, and the Common Musk Turtle. The wetland is of sufficient quality to support a population of Bullfrogs. Ten (10) different provincially rare (S1 to S3) vegetation communities were also identified within the watershed. The faunal inventory recorded the presence of area-sensitive bird species. Some areas of forest are extensive enough to provide interior forest habitat. In addition, the forested areas within the watershed contain numerous amphibian woodland breeding ponds. The beach shoreline provides significant opportunities for turtle nesting, and many areas within the watershed provide habitats for species of conservation concern. Many areas within the watershed are located on sections of Big Creek and/or its tributaries which function as animal movement corridors.

Finally, it is important to note that this very extensive and diverse wetland is extremely productive with respect to wildlife breeding, especially marsh birds. The conditions which lend themselves to this area being such an extremely productive wetland are largely due to the fact that most of the wetland area is privately owned and managed. This wetland would not be as productive biologically if this area was intensively used by the public during the breeding season. The current owners and managers are to be commended for their outstanding stewardship and management of their properties.

7.0 Synthesis of Technical Findings

7.1 Correlations and Analysis

Natural Heritage, Water Quality, and Water Quantity

Wetlands are effective in improving water quality by removing and transforming both organic and inorganic materials, including human waste, toxic compounds, and metals, from inflowing waters (National Research Council, 1992). Wetland attributes that make them effective in improving water quality include the following (adapted from Mitsch and Gosselink, 1986):

- As water floods into wetlands from rivers and streams, its velocity decreases, causing an increase in sedimentation. Thus, chemicals sorbed (stick) to sediments are removed from the water and deposited in the wetlands
- A variety of anaerobic and aerobic processes function to precipitate or volatilize certain chemicals from the water column
- The accumulation of organic peat that is characteristic of many wetlands can ultimately lead to a permanent sink for many chemicals
- The high rate of productivity of many wetlands can lead to high rates of mineral uptake by, and accumulation in, plant material with subsequent burial in sediments
- Shallow water coupled with the presence of emergent vegetation leads to significant sediment-plant-water exchange.

Runoff from agricultural land often puts excess nitrogen and phosphorous, the components of fertilizers, into rivers and lakes. Wetlands can absorb some of these nutrients, improving water quality. Most however is buried in sediments and utilized during wetland plant growth at a later date. Thus, wetlands possess an inherent ability to trap nutrients (Niering, 1985).

As reported in the study of water quality within Big Creek, relatively lower total suspended solids (TSS) levels were observed in the marsh and nearshore samples, compared to samples from stations upstream on the tributaries. Mean TSS levels at these sites were well below the Provincial Water Quality Objective (PWQO) benchmark value of 25 mg/L. This is to be expected with a riverine at mouth marsh wetland type, whereby the channel widens significantly near the mouth of a watercourse decreasing flow velocities and causing sediments to settle out.

Most of the total phosphorus (TP) concentrations observed in the marsh and nearshore sites were higher than the Provincial Water Quality Objective (PWQO) limit of 0.03 mg/L. However, levels in the marsh and nearshore sites were significantly lower than those found within the tributaries upstream. This indicates that the existing wetland vegetation may be assimilating phosphorus and that organic phosphorus may be sorbed to sediments and settled out in the marsh, therefore providing a benefit related to this water quality parameter, prior to the water flowing out into Lake Erie.

Nitrate levels in the marsh and nearshore sites were found to be well below the Canadian Environmental Quality Guidelines (CEQG) limit of 2.93 mg/L. The CEQG limit is published by the Canadian Council of Ministries of the Environment (CCME) . No exceedances of the limit were observed in any of the samples collected at these sites during the study period. Nitrate levels at these sites were significantly lower than those found in the tributaries upstream of the marsh. This indicates that the existing wetland vegetation may be assimilating nitrates, therefore providing a benefit related to this water quality parameter, prior to the water flowing out into Lake Erie. As well, organic fractions of nitrogen may be sorbed to sediments and settled out in the marsh.

Chloride levels in the marsh and at the nearshore sampling were well below the Environment Canada benchmark value of 210 mg/L. The lower concentrations observed at these sites could be attributed to the dilution factor. In general, higher levels of salt are detrimental to plant life, and may result in salt-resistant species (such as Phragmites) dominating. Therefore while chloride levels are low in the Big Creek marsh, monitoring must be continued.

E.coli levels tend to be high at all the tributary sites in the Big Creek watershed, however most of the marsh and nearshore levels are well below the Provincial Water Quality Objective (PWQO) recreational guideline limit of 100 CFU/100mL. Also, the E.coli levels in the marsh are significantly lower than the nearshore levels. This could be attributed to removal by predator aquatic plants (Karim, et al., 2008) and settling (Khatiwada and Polprasert, 1999) in the marsh.

Finally, the benthic invertebrate community observed in the marsh was of good quality, while upstream sites were found to have very poor benthic quality. This is directly correlated with the trends observed within the other water quality parameters, which show an improvement in water quality as you travel downstream, with the wetland at the mouth of Big Creek exhibiting the highest water quality with the lowest concentrations of contaminants.

The water levels within the marsh have an effect on wetland biodiversity and water quality. While the existing marsh Operational Plan written by Ducks Unlimited Canada in 2001 is acceptable insofar as recommended relative levels overtime, the management of the marsh could benefit from an extended period of shallow water immediately following a dewatering of the marsh. This dewatering could be as a result of natural deficits in water availability or deliberate pumping out of the basin in order to initiate re-vegetation (i.e. a drawdown). If the water levels are managed as per the Natural Heritage

Recommendations section and associated details in the Appendix, this will allow for a sustained growth of shallow water marsh vegetation communities. This additional diversity would include Bulrush Mineral Shallow Marsh Type (MASM1-2) and Arrowhead Mineral Shallow Marsh Type (MASM2-3) which was noticeably scarce within this site. Most of the aerial extent of wetland was composed of the deeper water American Lotus Floating-leaved Shallow Aquatic Type (SAF_1-2) Community, which while valuable as a provincially rare community type, is indicative of a much later stage (i.e., deeper water stage) in a marsh's

successional cycle. The recommended changes to the existing marsh Operational Plan (see Appendix) would therefore result in a greater extent of robust emergent vegetation over time. This in turn will increase nutrient uptake by the emergent vegetation from the water, thus enhancing one of the wetland's prime functions of improving water quality.

8.0 Recommendations

8.1 Natural Heritage

Species at Risk and Faunal Populations

Prothonotary Warbler Population Recovery

Concerted efforts should be made to reduce local populations of feral cats, as these pose a significant threat to many native bird populations including such species as the Endangered Prothonotary Warbler. Any comprehensive control program, developed from recommended wildlife control manuals (Fitzwater, 1994; University of Nebraska, 2010) however should not include the option to rerelease feral cats back into the natural environment, due to the severe predation effects from these animals.

In addition, in order to reduce the local population of House Wrens at Holiday Beach Conservation Area, which may be affecting the recovery of Prothonotary Warbler populations due to competition (OMNR, 2011a), it is recommended that any bird houses associated with seasonal campsites be removed and prohibited within the Conservation Area. Artificial nest boxes designed for Prothonotary Warblers should be closely monitored for House Wren activity. These boxes should be temporarily taken down until such time as the local House Wren population is significantly reduced.

The slough areas along the Lake Erie shoreline, inland of the beach, currently provide the best habitat for the local Prothonotary Warbler population. In the event that future dewatering events take place within the Big Creek marsh (whether intentional or incidental as a result of drought), it is recommended that these slough areas be kept as wet as possible in order to sustain the population.

Raccoons and Turtle Populations

Intensive predation by raccoons on Threatened populations of Blanding's Turtles and Eastern Musk Turtles may be severely inhibiting the sustainability of these populations. This watershed would greatly benefit from an intensive trapping program for raccoon, especially in the lower reaches of the watershed, near Lake Erie. In addition, other raccoon population control methods, as outlined in the Prevention and Control of Wildlife Damage Manual (Boggess, 1994), should also be considered.

Invasive Species

***Phragmites* Management**

As revealed through ELC vegetation community mapping, over 300 acres (120 hectares) of Phragmites-dominated vegetation exists within the sites surveyed in 2009. The OMNR has published a Best Management Practices (BMP) manual (OMNR, 2011b) which includes comprehensive recommendations for the control of Phragmites. This document is included in the Appendices for reference.

The vast majority of the stands of Phragmites occurred in standing water, however, those water depths were very shallow and at an approximate elevation of 174.60 m GSC. This elevation coincides with the maximum water depth within Big Creek before spilling out into Lake Erie. Therefore, Phragmites cannot be controlled through flooding, as this requires water depths of 1.5 metres deep (OMNR, 2011b).

For specific stands of *Phragmites*, individual landowners are recommended to consult the BMP manual for the option(s) available to them for control. Not all options may be implemented in all circumstances. In addition, it must be realized that until such time as there is a comprehensive provincial-wide control program (such as the biological control implemented for Purple Loosestrife in the late 1990's), any attempts at *Phragmites* control will require implementation of an ongoing program, to prevent re-establishment. In many instances this may prove to be extremely costly and labour intensive in the long term. However, it is still recommended that landowners attempt to implement the recommendations from the BMP manual to the best of their abilities in order to reduce current populations and prevent further spread of this highly invasive exotic plant.

Water Level Management

While the existing Operational Plan written by Ducks Unlimited Canada in 2007 is acceptable insofar as recommended relative levels overtime, the management of the marsh could benefit from an extended period of shallow water immediately following a dewatering of the marsh. This dewatering could be as a result of natural deficits in water availability or deliberate pumping out of the basin in order to initiate re-vegetation (i.e. a drawdown). If the water levels were managed in the first year following a dewatering to achieve a maximum average depth of 10 cm (4 in), in the second year a depth of 10-20 cm (4-8 in), and in the third year depths averaging 20-30 cm (8-12 in), then the resulting diversity of the marsh would be greater than at present. This diversity would include a higher component of shallow water marsh communities, such as Bulrush Mineral Shallow Marsh Type (MASM1-2) and Arrowhead Mineral Shallow Marsh Type (MASM2-3) which was noticeably scarce within this site, considering the last dewatering occurred only 4 years prior, in 2005. Most of the aerial extent of wetland was composed of the deeper water American Lotus Floating-leaved Shallow Aquatic Type (SAF_1-2) Community, which while valuable as a provincially rare community type, is indicative of a much later stage (i.e., deeper water stage) in a marsh's successional cycle. Therefore, revisions to the existing water level Operational Plan are recommended in order to better facilitate the growth of rich hemi-marsh within the lower Big Creek Marsh basin. These revisions are detailed in the Appendix.

In addition, if future dewatering events are planned for the main Big Creek marsh, it is recommended that those events occur as quickly as possible to trigger mass germination of the marsh seedbank in the resulting mudflats. Once vegetation is well established, water should be added to encourage dense vegetation growth. This will assist in preventing the spread of Common Reed (*Phragmites australis*) which would most likely spread aggressively and extensively during slow removal and drying of the marsh.

While it is recognized that the purpose of water level management is to enhance wetland vegetation, there is the very real possibility that temporary draw-downs of water will result in a reduction of available habitat for fish living in Big Creek. The Operational Plan should incorporate plans for addressing the potential for significant fish die-offs as a result of the lower water levels during dewatering events. This plan may include fish salvage and temporary relocation efforts. The location of water refugia in the system in specified areas should also be detailed as part of the plan.

For Site #23 (Mans Marsh), it is recommended that a site specific wetland management plan be written, in consultation with staff from ERCA and Ducks Unlimited Canada in order to investigate the potential to manage the wetland areas independently of the Municipal Drainage system.

Restoration Opportunities

Restoration opportunities are designed to focus on restoring connectivity to fragmented patches within the landscape, consolidate patches to increase core areas and reduce edge habitat, and buffer wetlands and aquatic habitat and wildlife from adjacent land uses. ERCA has completed an update to the Biodiversity Conservation Strategy (ERCA, 2002) which forms part of the Essex Region Natural Heritage System Strategy (ERNHSS) (ERCA, 2013). The following Table and Figures from the ERNHSS summarizes the proposed restoration opportunities within the entire Big Creek subwatershed, including those areas not surveyed as part of this Watershed Plan in 2009.

Table 3 Proposed Restoration Opportunities

Restoration Opportunities			
Proposed Restoration	**Hectares**	**Acres**	**%**
Wetland Buffer	1101.46	2721.76	14.42
Riparian Buffer	353.64	873.87	4.63
Other Restoration Opportunities	20.99	51.87	0.27
Total Restoration Opportunties	**1476.10**	**3647.50**	**19.33**
Status Quo Anthropogenic	**4601.21**	**11369.79**	**60.25**
Total Land Area	**7637.11**	**18871.63**	**100.00**

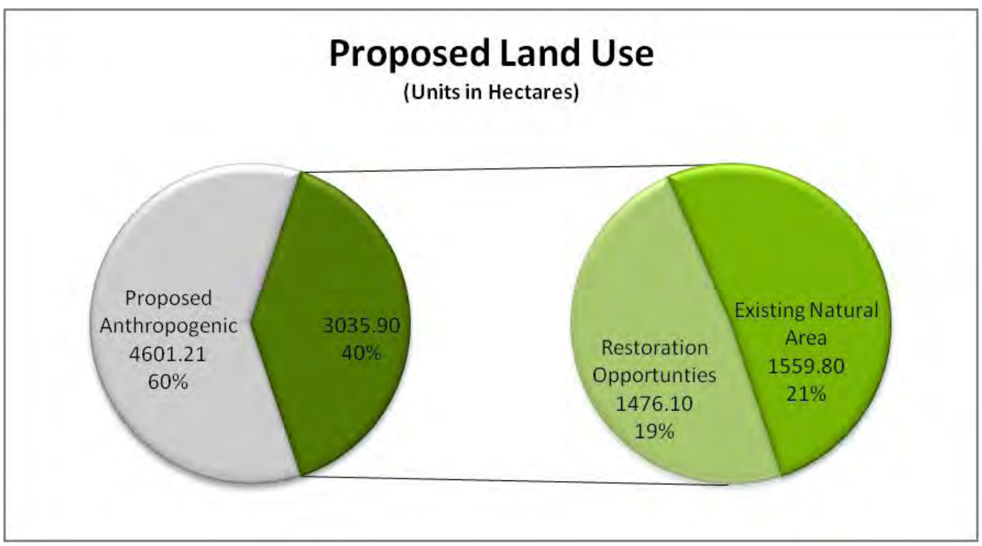


Figure 4 Land Use Proportion Following Restoration

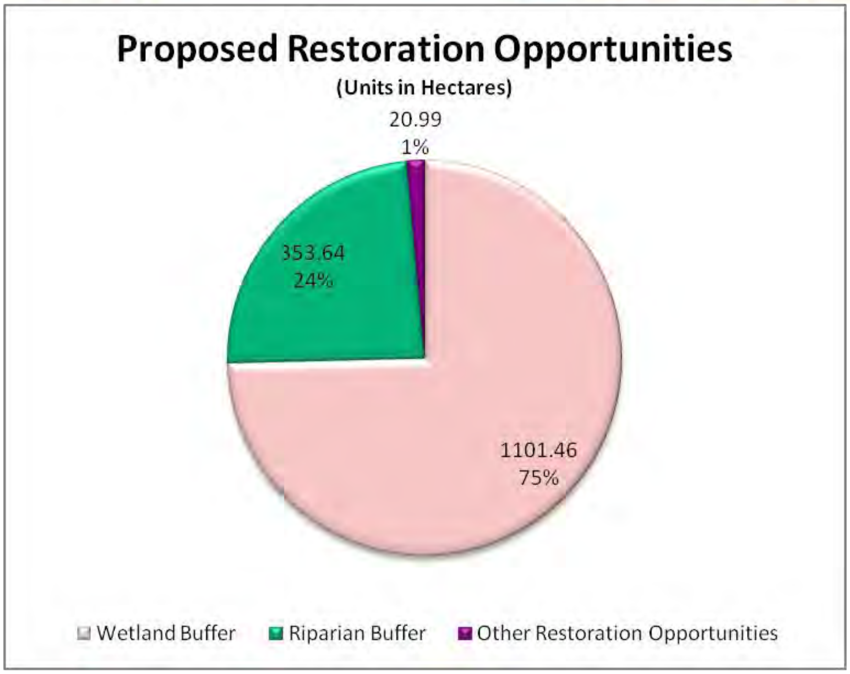


Figure 5 Proposed Restoration Opportunity Proportions

As part of ERNHSS, restoration opportunities across the entire Essex region were prioritized based on a set of criteria which emphasized the benefits of restoration due to the proximity to significant core areas, physiography, and linkage/buffering potential, etc. For the Big Creek watershed, these priority restoration opportunity areas were then analyzed in the context of the data gathered as a result of the natural heritage inventories and analyses. Further prioritization of the restoration opportunities for Big Creek was accomplished due to consideration of FQI values, ANAGNPS analyses, Species at Risk location data, etc. The resulting prioritized restoration opportunities for the Big Creek watershed are depicted on the following map.

For those sites with the highest FQI values (sites 6&13, 52, 4 and 54) the following specific recommendations are made.

Site 6 &13

Habitat restoration for this site includes restoration of agricultural lands located on the east side of the properties, from the existing extent of natural vegetation eastward. This would provide additional wildlife nesting habitat and buffering of the existing Provincially Significant Wetland (PSW), as well as riparian habitat along the various watercourses that enter the main Big Creek marsh basin. This area of proposed restoration is extensive enough to include significant diversity. It is recommended that a site specific restoration plan be developed for this site in order to facilitate appropriate restoration which maximizes diversity and is complementary to the existing vegetation communities, as well as specific to the needs of the resident wildlife. Furthermore, additional restoration is recommended for the agricultural lands located on Knapp's Island. The goal would be to increase the amount of interior forest on Knapp's Island.

Site 52
Habitat restoration for this site includes restoration of adjacent agricultural lands or open disturbed lands to create a 240 metre buffer to the Provincially Significant Wetland (PSW). This area of proposed restoration is extensive enough to include significant diversity. It is recommended that a site specific restoration plan be developed for these lands in order to facilitate appropriate restoration which maximizes diversity and is complementary to the existing vegetation communities, as well as be specific to the needs of the resident wildlife. In particular, areas associated with the restoration of the Soda Ash Settling Basin (SASB) should be restored to an alvar type of vegetation community if possible.

Site 4
The site could be enhanced in the following ways. The large trees currently in the extensive picnic area between the southerly campground the beach are almost exclusively Silver Maple. As these trees are showing signs of "old age" and mortality may occur within the next decade, additional trees should be planted as replacement trees as soon as possible. The tree species selected should be complementary to the existing vegetation communities.

Site 54
Habitat restoration for this site includes restoration of adjacent agricultural lands north and east of the site to create a 240 metre buffer to the Provincially Significant Wetland (PSW).

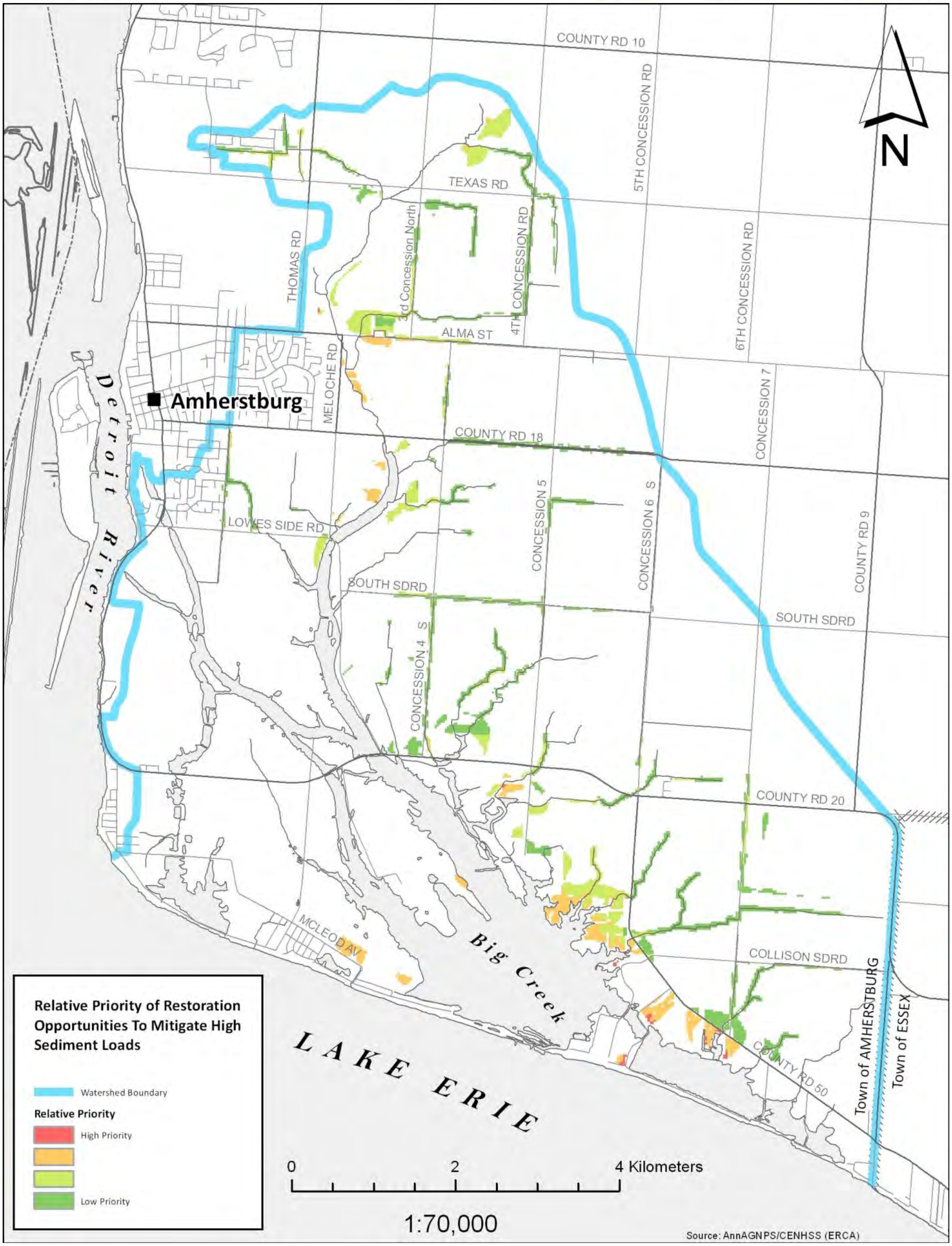


Figure 6 Relative Priority of Restoration Opportunities to Mitigate High Sediment Loads.

8.2 Surface Water Quality

It is strongly recommended to continue water quality monitoring with flow measurements. It is also recommended to test soil samples and groundwater for indicator parameters and work with the MOE on devising a strategy to mitigate risks posed by potential chloride contamination due to soda ash basin leak. Based on the results of the water quality monitoring study, best management practices are recommended below:

- Conducting regular septic system inspections and maintenance for nutrient and bacterial loading reduction
- Using phosphorus free lawn fertilizer for nutrient loading reduction
- Implementing road salt management for mitigation of chloride contamination, which includes spills action plan to avoid or mitigate salt-laden runoff especially at bridges over watercourses
- Naturalizing shorelines for soil erosion control
- Managing the application of pesticides in order to mitigate pesticides contamination
- Agricultural best management practices for soil erosion control and nutrient loading reduction, including buffer strips, soil erosion control structures (e.g. rock chutes), header tile retrofits, constructed wetlands, cover crops, management of nutrient storage and application, livestock waste management
- Managing stormwater runoff, including improved treatment efficiencies at the Crownridge and Kingsbridge facilities, creation of rain gardens and the use of rain barrels
- Working with MOE to develop a spills action and a long term management plan for the industrial facility soda ash basin

These recommendations may be used to develop new, or revise existing, Town of Amherstburg policies for the protection and health of the watershed. Some of these recommendations are specific to certain land uses e.g. urban residential, industrial, rural residential and agricultural. The recommendations may also tie in with the proposed source water protection plan policies, intended to protect the sources of drinking water.

8.3 Storm Water Management

All new development on land parcels greater than .25 hectares should only proceed with a full implementation of proper stormwater management measures. Stormwater Management infrastructure should address both quantity and quality and modify and regulate release rates ensuring that appropriate provincial standards are being met and apply all current best management practices relative to treating the impacts of the outflow and maintenance of the stormwater infrastructure.

The positioning and ultimate placement of the stormwater facilities needs to be planned for well in advance of the proposed development. This infrastructure needs to be readily accessible by the municipality who is the eventual owner and operator of all of these types of facilities. The facility design should mirror natural conditions such that pond side slopes and configurations of pools and wetlands mirror those found in nature. These types of design concepts allow for a more robust facility increasing sustainability and functionality during operational cycles as flatter slopes and ponds that have appropriate length to width ratios require lower active maintenance. It is imperative that maintenance is undertaken on a planned regular timeframe with processes that are prescribed in the municipalities design standards manuals. These facilities, if improperly maintained, readily fall into succession by the Natural environment and may not function as originally intended. Proper maintenance will preserve the facilities original design intent while not becoming a legislative burden or problem in the future.

With regard to proper placement of these structures, it is critical to provide access for maintenance purposes and also to have adequate separation distance from Natural Hazards. In some instances, it is almost counter intuitive to have this infrastructure separated from the ultimate drainage outlet; however, this infrastructure is the means to mitigate the potential negative impacts of development from a drainage and/or runoff control perspective. Infrastructure should be positioned safely while ensuring that overland routing and flow routes are properly addressed and provided for.

The science of stormwater design and facility design is now more so than previously a dynamic and changing field. Design professionals are now being challenged to incorporate Low Impact Design (LID) components and processes within the treatment train. This process attempts to better imitate a natural process of stormwater management that would allow for infiltration of polished runoff back into the soil column thereby lessening the impact on existing municipal infrastructure. The challenge that would be faced with utilizing these processes within the Big Creek Watershed is that the predominantly clay soils have a very low permeability. In addition climate change is affecting soil moisture content and infiltration rates. Notwithstanding both of the previous points, properly designed and placed stormwater management facilities will need to have regard for a changing climate and should consider replicating natural drainage processes and attempt in all cases to redirect polished runoff back into the local soil profile mirroring predevelopment conditions. The results of the water budget analysis confirm that the Big Creek basin is in a deficit with respect to input. The water resource supplies in all cases need to be managed to attempt to modify the current water budget deficit towards more of a balanced equation.

The science of stormwater quality treatment has observed some advances during the last two decades. The processes available now for treatment range from mechanical to filtration to root zone uptake. In every condition full consideration needs to be given to manage stormwater quality from a treatment train approach and not only from an end of pipe perspective. There are always instances of having no other choice but to proceed with an end of pipe solution, however, this situation should not define the norm. Proper planning for stormwater treatment processes should be incorporated at the start of the planning process and not be left to the tail end of the development process.

8.4 Base Flow Protection and Augmentation

As discussed in previous chapters the overall historic size of the Big Creek Watershed has been diverted back to less than half of the natural or pre European settlement original basin size. The systematic diversions of firstly the portions of the watershed which now drains to the man made Richmond Drain which is approx. 3200 hectares and then the Long Marsh Drain which further diverted an additional 4800 hectares, leaves the remaining Big Creek basin with an area of 7300 hectares. The truncated Big Creek basin has now had a functioning lifetime of approx. 110 years. The elimination of the upper reaches of the water basin has removed a source of surface water from the basin that would have provided the potential additional flushing, and introduced potential flow, days after rainfall events that no longer is provided for today. This possibility of introduced flow would have been possible due to impounded areas, which likely existed behind blockages in the old Marsh Creek that then would have naturally released over time after rainfall events.

The compacted tributaries that today feed into the lower Big Creek basin receive only rainfall and direct surface water runoff from those areas immediately riparian to the lower basin and the remaining portions of the Big Creek channel. Historically runoff from as far as the Town of Harrow would have been conveyed down the historic Marsh Creek to the area of watershed now referred to as Big Creek. There has been discussion relative to augmenting base flow through to Big Creek. The following sections will address some of the considerations and the limits and affects of some of those concepts.

Sources of water supply

The obvious first consideration to a possible water supply for base flow would be to attempt a reconnection of the upper Marsh Creek basin flows that historically drained towards the current Big Creek. There is not a means to physically reconnect or divert the Richmond Drain flows towards the current Long Marsh from a practical perspective as the diversion that historically proceeded is several kilometers to the east and the grade differential at that location now is over 3.0 meters lower than the upper reach of the Long Marsh, so this supply of upper basin water is not available. The remaining portion of historic Marsh Creek as referred to in a 1790 Mcniff Survey (see figure xxxx) has now been converted to a municipal drain that for almost a century has been identified as the Long Marsh Drain. The Long Marsh Drain diversion at the approx. location of County Road 10 and the 3rd Concession of Amherstburg has an invert elevation at that location that is more than 2.8 metres deeper than the remnant Big Creek Valley land that immediately abuts the diverted waterway. The flows and volume of water in the Long Marsh are substantial; however the improved hydraulic conveyance of this waterway together with the amount of infrastructure and development abutting the channel eliminates the opportunity to hold and or impound water significantly to redirect flows towards the Big Creek basin. There are also many considerations to address before attempting a reconnection at this location that will be discussed further in a following section.

A connection to the Detroit River existed historically in the vicinity of what now is the approx. location of the Canadian Coast Guard base. This connection however, after reviewing topographical mapping reveals that flow for the most part would have been draining back towards the Detroit River as the area in and around the Lowes Sideroad in elevation exists at a higher ground elevation than the high long term monthly mean elevation of the Detroit River. So the consideration of providing an opportunity to augment base flow at this location did not naturally occur and the benefits to sourcing water from this location would present additional challenges and considerations not only from a water quality and unnatural source perspective but also that the Detroit River source would only feed from a practical perspective the Back Creek which outlets to the lower Big Creek basin but does not provide flow to the main Big Creek channel.

There is the potential to consider purely from a source perspective a ground water source, however this would necessitate drilling of a well or wells and although there are many active ground wells within the general area, there would need to be further consideration given to location of outlet, pumping rate and operational costs that this study has not been charged with considering. In addition the thermal regime of a ground water source would need further treatments and or considerations

There is no evidence of an active spring or ground water flow which historically drained through Marsh Creek. A review of soils mapping indicates that there are pockets of sandy soils which flank the historic Marsh Drain corridor, however this surficial geology is not conducive to groundwater upwelling and or having active artesian wells present.

Impacts on Natural Heritage Values

The consideration of augmenting base flows allows in general terms the potential for fresh water to be added to the existing system that should if managed properly provide many natural benefits. This is premised on the fact that a fresh water supply could be properly restricted and have quality control provided to eliminate contamination and erosion and sedimentation impacts. A fresh water source would replenish diminished oxygen levels due to stagnant water present in areas where there is no measureable flow. The determination of the rates of flow and positioning of possible sources requires significant additional investigation work including a benefit cost analysis and further technical studies. A significant concern for the Natural Heritage values of the upper Big Creek exists relative to any change in what has now existed for water supply for over a century. The extent of the mapped Provincially Significant Wetland exists up to the practical limits of the Big Creek Channel. Any measureable change to water level and or flow at this location could only be considered with full accountability to the natural heritage values present at this location and others along the waterway. Significant life science work and assessments would need to accompany any physical science considerations relative to low flow augmentation and these processes are well beyond the consideration of this report.

8.5 Land Use Planning and Policy

The Town of Amherstburg as well as provincial and federal ministries and departments will play a significant role in the implementation of the Big Creek Watershed Plan. Many of these governmental agencies have policies, by-laws and programs in place and the ability to implement management actions recommended in this watershed plan. However, it is recognized that the involvement and support of the residents of the Town of Amherstburg is also of paramount importance to the successful implementation of the Watershed Plan. It is suggested that recommended policies are considered for inclusion in municipal official plans, by-laws or specific programs over the next five years. However, given that the Town of Amherstburg is undergoing official plan review in the next few years, it will be practical to consider as many recommended policies as possible through this planning process. In addition, the Essex Region Conservation Authority is committed to updating its policies in accordance with the Big Creek Watershed Plan.

Within Essex County two Source Protection Plans have been prepared in compliance with the Clean Water Act, 2006. These plans are the Thames-Sydenham and Region Source Protection Plan and the Essex Region Source Protection Plan. Both plans have been submitted to the Ministry of the Environment for approval and readers should refer to these plans for specific policies and for specific policies that may apply to the vulnerable areas which may restrict or prohibit certain land uses or activities. The Source Protection Plans and associated technical studies (Assessment Report , 2012) looks at the current and future sources of municipal residential drinking water, identifies the potential threats to these sources and includes policies for actions and programs to reduce or eliminate these risks. Once the Source Protection Plans and Assessment Reports are approved, as amended from time to time, all municipal decisions under the Planning Act shall confirm to the significant threat policies and have regard for other policies. According to the Source Protection Plans, the most prevalent type of Significant Drinking Water Threat in the Essex Region is the storage, handling, or transportation of large volumes of liquid fuels.

The County of Essex is completing an update to the Official Plan (anticipated to be completed in early 2014, County of Essex, 2013). At that time land use planning policies and schedules pertaining to the Big Creek Watershed will need to be incorporated into the Town of Amherstburg's Official Plan and Zoning By-laws. The Essex Region Natural Heritage System Strategy (ERCA, 2013) provides recommendations for both the County and all lower tier municipalities for appropriate land use designations to reflect the natural heritage recommendations. The Town of Amherstburg in partnership with ERCA should review the ERNHSS report in conjunction with the Big Creek Watershed Plan to provide recommended land use designations that reflect the appropriate levels of protection, enhancement and restoration as identified. In addition, it is recognized that voluntary stewardship and land acquisition and securement activities are needed to implement natural heritage systems in the Big Creek Watershed and the Town should adopt supportive policies that reflect the recommendations of the following section related to stewardship and education and awareness initiatives.

8.6 Implementation and Policy Direction

Many specific management actions have been identified to achieve the goals and objectives of each component of the watershed plan. Implementation of the Big Creek Watershed Plan is dependent on the adoption and facilitation of recommended management actions relating to regulations and planning, stewardship, education and awareness, land securement, and monitoring and reporting. The Big Creek Watershed Plan is intended to inform and guide municipalities, provincial and federal governments, and the Essex Region Conservation Authority in updating applicable policies and programs for protection, conservation and enhancement of the Big Creek Watershed. ERCA has prepared a document titled "Your Conservation Legacy" which identifies various mechanisms to implement recommendations of the Big Creek Watershed Plan.

The Big Creek Watershed Plan provides direction to local organizations and residents in the watershed with regards to best management practices and suggested actions for watershed stewardship. Implementation of these stewardship actions will be effective if existing and future organizations coordinate efforts in the watershed. Finally, monitoring and reporting of environmental conditions and implementation of the watershed plan are needed to ensure that steps to reach the goals and objectives of the watershed components are occurring and are effective. The following sections outline the

implementation mechanisms and timelines for each management action mechanism.

Stewardship

Many recommended management actions can be achieved through voluntary actions by landowners, residents, rural agricultural and non-agricultural businesses, and urban businesses. It is recommended that a coordinated approach with various partners be adopted to enhance the delivery of stewardship projects across the watershed. It is also recommended that the ERCA, through the Clean Water – Green Spaces Program, facilitate and coordinate partner communication through regular meetings and updates.

Certain stewardship actions are encouraged and deemed a priority when the implementation of a project benefits many ecological functions. Table 4 addresses the priority stewardship actions that should be continuously encouraged over a long timeframe, as well as stewardship actions that may address site-specific needs as they arise. It is recommended to further implement the ERCA Clean Water – Green Spaces Program in the Town of Amherstburg to facilitate rural stewardship actions.

Education and Awareness

In order to achieve the goals and objectives associated with each watershed component, education and awareness initiatives need to be employed. In addition, communication, in the form of education and awareness, is required to see successful implementation of recommended regulations and planning, stewardship and land acquisition management actions. It is also recommended that partner activities be coordinated in consultation with the ERCA and the Town of Amherstburg, to ensure consistent messaging, avoid duplication, and facilitate integration of funds and other resources.

Education and awareness initiatives will be delivered to a variety of audiences including urban and rural residents and landowners, the agricultural community, business and industry, schools, community organizations and the municipality. Avenues for implementation of initiatives will include, but not be limited to, workshops, seminars, watershed tours, the ERCA website, print material and the use of media. Initiatives will be geared toward topics that help to achieve each watershed component goal and objective.

Table 4 Stewardship Action Implementation

Stewardship Action	Priority and Timeline	Integrated Ecological Benefits	Delivery Agents*	Potential Funders*
Increase natural native cover in the natural heritage system as per ERNHSS	High, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species • Terrestrial natural heritage	A'burg ERCA	A'burg ERCA COA DUC HSP NCC
Increase natural cover in riparian areas as per ERNHSS	High, long term	• Surface water quantity and quality • Aquatic habitats and species • Terrestrial natural heritage	A'burg ERCA	A'burg ERCA DUC HSP NCC

Stewardship Action	Priority and Timeline	Integrated Ecological Benefits	Delivery Agents*	Potential Funders*
Increase and enhance specific habitat types (wetlands, tallgrass prairie, interior forest)as per ERNHSS	High, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species • Terrestrial natural heritage	A'burg ERCA	A'burg ERCA COA HSP NCC
Encourage and assist with rural best management practices associated with land uses (woodlot management, agricultural practices, rural residential practices)as per ERNHSS	High, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species • Terrestrial natural heritage	A'burg ERCA	A'burg ERCA OMAF
Encourage and assist with urban best management practices associated with land uses (lot level water management, urban stream management, water and energy conservation)	High, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species • Public health and well-being	A'burg ERCA	A'burg ERCA MOE
Encourage private well upgrades and decommissioning to protect groundwater quality and domestic drinking water supplies	High, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species	A'burg ERCA	A'burg ERCA MOE
Enhance environmental features in public spaces as per ERNHSS	High, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species • Terrestrial natural heritage • Public health and well-being	A'burg ERCA	A'burg ERCA NCC
Encourage private septic and chemical or fuel storage best management practices	Medium, long term	• Groundwater quantity and quality • Surface water quantity and quality • Aquatic habitats and species	A'burg ERCA	A'burg ERCA MOE
Removal of online ponds and manmade stream barriers	Medium, site- or situation-specific	• Surface water quantity and quality • Aquatic habitats and species	A'burg ERCA	A'burg ERCA

Stewardship Action	Priority and Timeline	Integrated Ecological Benefits	Delivery Agents*	Potential Funders*
Enhance or restore in-stream habitat including bank stabilization and erosion control	Medium, site- or situation-specific	• Aquatic habitats and species	A'burg ERCA	A'burg ERCA

Delivery Agents
A'burg - Town of Amherstburg
ERCA - Essex Region Conservation Authority

Potential Funders
A'burg – Town of Amherstburg
ERCA – Essex Region Conservation Authority-under the Clean Water/Green Spaces Program
-with funding partners *Trees Ontario*
Ontario Power Generation
Department of Fisheries and Oceans
Environment Canada
Ministry of Natural Resources
COA – Canadian Ontario Agreement
DUC – Ducks Unlimited Canada
HSP – Habitat Stewardship Program – Environment Canada
OMAF – Ontario Ministry of Agriculture and Food
MOE – Ministry of the Environment
NCC – Nature Conservancy of Canada

8.7 Landowner Stewardship and Public Education

Watershed planning is the responsibility of many levels of leadership and can best be undertaken in a collaborative manner. Protecting, restoring, and enhancing watershed health requires the cooperation of all stakeholders within the watershed. Every person has an impact on the environmental, social, and economic health of the watershed through their everyday actions.

The Essex Region Conservation Authority will initiate and lead landowner stewardship and public education by building on existing stewardship and education programs to promote best management practices. Education on these practices will be provided for landowners, residents, various business sectors, as well as organizations such as industry associations and professional organizations with the following priorities:

Active Engagement and Participation

Actively engaging and participating in the protection, restoration and enhancement of the watershed is crucial. Personal observations and insight add to the local knowledge base that can help create uniquely appropriate and creative solutions for local problems and opportunities. Restoration opportunities within the watershed largely occur on private lands, providing opportunities for stakeholders to directly and positively enhance watershed features and functions. Participation by residents, landowners, schools, and community groups ensures that an appropriate, beneficial and tailored management approach can be achieved in the watershed.

Continuous Learning and Increasing Awareness

Watershed and resource management actions are constantly evolving as conditions, science, and technology change. All stakeholders should be aware of how impacts to the Big Creek watershed affect the surrounding watershed. Sharing ownership and responsibility for the outcomes of the watershed plan helps to create the commitment needed for implementation at all stages. It will benefit from early and continuous engagement of the stakeholders in the watershed planning process.

Responsible Land and Resource Stewardship Practices

Every resident, land owner, business and guest in this watershed has an impact on its ecological features and functions. Through messaging this concept, positive changes will protect the Big Creek watershed for generations to come. Best Management Practices will be promoted to mitigate or prevent impacts to watershed quality. These approached are intended to increase awareness on the benefits of landowner stewardship and encourage positive changes in behaviour.

Implementation, Acceptance and Support for the Watershed Plan

The success of this Watershed Plan is dependent upon the effectiveness of its implementation. To implement the Plan, it must first be accepted by municipalities with full support provided so that the recommendations of the Plan can be put into action through planning policy. Secondary, to this priority is the acceptance and understanding of the Plan by the development community, residents and other interested stakeholders. The structure of this Plan provides a focus on the end-user.

8.8 Climate Change

Climate change is defined as a change of climate, which can be attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (Environment Canada 2006). Climate change is not a localized phenomenon. Occurring across the globe, effects have been felt by many different ecosystems and in many different countries.

Within the Great Lakes basin, ecosystem changes due to climate change have been noted and are outlined by Chiotti and Lavender (2008):

- The ice cover season on the Great Lakes has been shortened by about 1 to 2 months during the last 100 to 150 years.
- Nearshore lake temperatures have increased at several locations since the 1920s. These increases are likely associated with extensive algae blooms and invasion of non-native species.
- Shifts in fish communities are expected to occur with declines in coldwater species in the Great Lakes. Warm water species such as Bigmouth Buffalo and Flathead Catfish are already being seen more frequently in the Great Lakes basin.
- Additional stressors on already fragile habitats such as coastal wetlands and terrestrial ecosystems may result in these habitats being unable to maintain their functions under increased climate change.

Changes are also expected to occur in water resources in the Great lakes basin, and will affect both groundwater and all surface water sources (Great Lakes, inland lakes, rivers, streams and ponds). Spring freshets (river flow from snowmelt) and extreme rainfall events will also change the way streams respond under a flood. Increasing winter temperatures will possibly cause the spring freshet to occur earlier and, because of more frequent winter thaws, the freshet will likely be lower, reducing the risk of spring flooding (Chiotti and Lavender 2008). In addition, projected increases in the frequency and intensity of extreme rainfall events will result in increased summer flood risks.

On a watershed scale, some of the expected effects of climate change include:

- Overall increase in risk of extreme and erratic weather
- Increase in risk of heavy-rapid rainfalls
- Increase in number of freeze-thaw cycles
- Increase in risk of flooding and drought events
- Increase in risk of bank erosion
- Increase in water turbidity and decrease in water quality
- Higher concentration of contaminants in lakes and streams, impacting water quality and

human health

- Redistribution, reduction and/or loss of wetlands
- Increase in stress on aquatic and terrestrial biodiversity
- Increase in stress on water management structures

The Essex Region Conservation Authority understands that climate change will exacerbate the stresses already present in local watersheds and believes that a comprehensive approach, including both mitigative and adaptive actions is needed to reduce and cope with the effects of climate change. Many local considerations relative to standard design and implementation mechanisms for development and construction activities need to be planning for response actions to address the concern for climate change. Such actions are being actively pursued by the ERCA in partnership with all local municipalities relative to updating Guidelines Policies and procedures for development and planning approvals, modifying municipal Development Standards Manuals and pursuing such additional processes as updating Intensity, Duration and Frequency Curves (IDF Curves) at the regional level. Policies in the Big Creek Watershed Plan will need to be brought in line with mitigative and adaptive actions recommended within local climate change strategies. In addition, during the creation of a local strategy, other local initiatives will be consulted. (Refer to Appendix *State of Climate Change Research in the Great Lakes Region*)

9.0 Monitoring and Evaluation

Monitoring and Evaluation

Successful implementation of the Big Creek Watershed Plan will require monitoring of many of the implementation components to ensure that the goals and objectives of the Plan are being achieved. A monitoring program involves the collection, interpretation and assessment of observations, field measurements, biotic sampling and analytical analyses of different facets of the environment, which can be used as indicators of the health or status of the resources. Monitoring includes both seasonal, annual or long-term assessments as well as periodic re-evaluations of the Plan.

Monitoring of the Big Creek Watershed is required to:

- Address identified data gaps, deficiencies, confirm/establish trends relating to the overall health of the ecosystem, and complete/progress the understanding of the hydrologic (surface and groundwater interactions) and ecological functions.
- Allow for the continued examination of the health/resiliency of the ecosystem using the present data as a baseline for comparative assessment. This will facilitate assessments of land use change (e.g. development), rehabilitative/restoration measures (e.g. reforestation, riparian buffer establishment), and the operational performance of the Permit To Take Water in order to establish compliance.
- Provide the quantitative and qualitative means to measure/assess how well the goals and objectives are being achieved by identifying which environmental targets are being met.

Data collection and public education are equally important to the success of the monitoring program. Where possible, public input should be solicited and incorporated into a monitoring database.

Reporting can occur in many formats including research papers and reports, annual monitoring reports and summaries, watershed report cards, newsletters and media materials. Reporting should focus on the needs of the intended target audience and recommend improvements for future monitoring and research programs and the Watershed Plan. This reporting is necessary to ensure that the implementation of the watershed management plan process is proceeding successfully.

Literature Cited

Boggess, E.K. 1994. Racoons. Pages C101-C108. In S.E. Hygnstrom, R., M. Timm, and G.E. Larson (eds) Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension Service, Lincoln, Nebraska, United States. *http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1038 &context=icwdmhandbook*.

Corkum, Lynda D 2010. Fishes of Essex County and Surrounding Waters. Essex Conty Field Naturalists' Club. Library and ARchieve Canada Cataloguing in Publication.

Essex Region Conservation Authority (ERCA). 2002. Essex Region Biodiveristy Conservation Strategy – Habitat Restoration and Enhancement Guidelines. Dan Lebedyk, Project Co-coordinator. Essex, Ontario. 181 pp.

Essex Region Conservation Authority. 2013. Essex Region Natural Heritage System Strategy - (An Update to the Essex Region Biodiversity Conservation Strategy). Essex, Ontario. 319 pages.

Fitzwater, W.D. 1994. House cats (Feral). Pages C45-C49. In S.E. Hygnstrom, R.. M. Timm, and G.E. Larson (eds) Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension Service, Lincoln, Nebraska, United States. *http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1031 &context=icwdmhandbook*.

Karim M.R., Glenn E.P., Gerba C.P. 2008. The effect of wetland vegetation on the survival of Escherichia coli, Salmonella typhimurium, bacteriophage MS-2 and polio virus. Journal of Water Health. Vol. 6(2):167-175 pp.

Khatiwada, N.R., and Polprasert, C. 1999. Kinetics of fecal coliform removal in constructed wetlands. Water Science Technology. Vol. 40: 109-116 pp.

Mitsch, W.J. and Gosselink, J. G.. 1993. Wetlands. (Second Edition) Van Nostrand Reinhold Co., NY. 722 pp.

National Research Council. 1992. Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. Washington, DC: The National Academies Press. 552 pp.

Niering, William A. 1985. The Audubon Society Nature Guides – Wetlands. Chanticleer Press, Inc. New York. 640 pp.

Ontario Ministry of Natural Resources (OMNR). 2011a. DRAFT Recovery Strategy for the Prothonotary Warbler (Protonotaria citrea) in Ontario. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario. i + 3 pp. + Appendix vi + 26 pp. Adoption of the Recovery Strategy for the Prothonotary Warbler (*Protonotaria citrea*) in Canada (Environment Canada, 2011).

OMNR. 2011b. Invasive *Phragmites* – Best Management Practices, Ontario Ministry of Natural Resources, Peterborough, Ontario. Version 2011. 17p.

Pegg, A. P. 1986. Fur Trade to Farmstead: A History of Renewable Natural Resources in the Essex Region 1750-1900. Essex Region Conservation Authority Publication. Essex, Ontario. 115 pp.

Richards, N., A. Caldwell, and F. Morwick, 1949. Soil Survey of Essex County, Experimental farm service and Ontario Agriculture College.

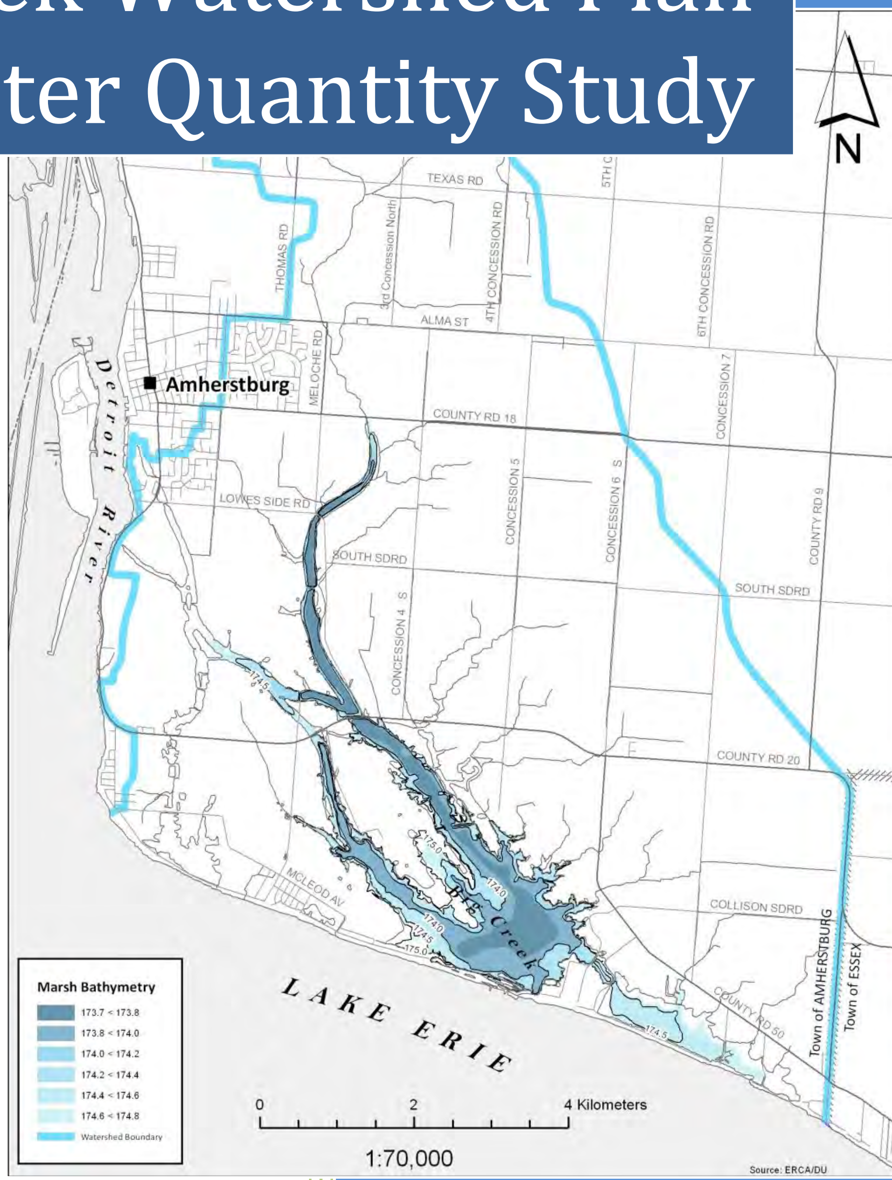
United States Geological Survey (USGS), 1999. National Water Summary on Wetland Resources. USGS Water-Supply Paper 2425. http: http://water.usgs.gov/nwsum/WSP2425/. Accessed: 07 Feb 2011.

University of Nebraska – Lincoln Extension. 2010. Feral Cats and Their Management. Publication number EC1781. Institute of Agriculture and Natural Resources, University of Nebraska – Lincoln. Lincoln, Nebraska, United States. *http://www.ianrpubs.unl.edu/sendIt/ec1781.pdf*.

Appendices

2011

Big Creek Watershed Plan Water Quantity Study



Essex Region Conservation Authority

Town of Amherstburg

9/22/2011

Big Creek Watershed Plan

Water Quantity Study

Introduction

A number of recent land and resource use activities and applications in the Big Creek watershed have highlighted the difficulty in assessing the watershed in terms of the varied natural resource values and community priorities that exist in the area. This has revealed the need for a watershed plan that can be used to make decision-making related to a variety of local activities and uses. The stakeholders of the Big Creek Watershed have embarked on the development of a water management plan as a proactive approach to planning and developmental activities. The water management process includes the assessment of the natural resources in the watershed and establishment of appropriate strategies for the protection or management of these features and processes under present and future conditions. The primary areas considered for this plan include water quantity, water quality and natural heritage. The plan must recognize the importance of creating an inclusive vision for the watershed which supports a vibrant agricultural industry, a wide variety of recreational opportunities (including hunting, bird watching and other passive uses) with plentiful opportunities for community growth.

Since European settlement, several alterations to drainage, re-routing of watercourses and clearing of natural features in the Big Creek Watershed have resulted in changes to hydrological and water quality regimes, and diminished ecological function. Two of the main alterations have to do with the Long Marsh Drain. The area that drains to the Richmond Drain and upper portions of the Long Marsh Drain used to flow into the present day Big Creek Watershed but were rerouted away many decades ago. The upstream (southwestern) portions of the Richmond Drain (about 3,200 ha) once drained into the Long Marsh Drain but are now rerouted into Cedar Creek. The upstream portion of the Long Marsh Drain (approximately 4,800 ha) was also connected to the lower portion of the present day Long Marsh Drain. As a result of these two changes, the Big Creek Watershed drainage area was substantially reduced by about 8,000 ha (over half of the current watershed), which in turn has affected the drainage characteristics and hydrology of the watershed. This is of particular significance from the low-flow point of view. Limited field surveys and anecdotal information has revealed that the Richmond Drain generally carries a substantially higher fraction of the baseflow throughout the year when compared to the present data Big Creek Watershed. The lack of water can also be attributed to the disconnection of one of the drains located on the southwestern portion of the watershed from the Detroit River, which likely has affected water conditions in the western leg of the watershed and marsh.

The present chapter summarizes the existing water quantity conditions of the Big Creek Watershed, including watershed hydrology and wetland water balance, which is reported on in greater detail in the Water Quantity Technical Study. An erosion characterization was also undertaken to provide estimates of non-point source pollutant loadings. This is followed by sections on the analysis of various marsh succession management scenarios under dry, average and wet conditions. The chapter also presents the result of a preliminary analysis on how the variations of climate and streamflow conditions affect the hydrologic regime of the Big Creek Marsh. This information, along with other reports on natural heritage and water quality, will be used for the development of the future water management plan.

The present study was carried out by a team consisting of the following:

Dr. Tirupati Bolisetti, Associate Professor, University of Windsor
Jeremy Wychreschuk, Past Director of Watershed Engineering, ERCA
Masihur Rahman, Research Associate, University of Windsor
Ian Wilson, Graduate Student, University of Windsor

Objectives

As stated in the main report, the following primary objectives have been identified:

- Complete a water quantity assessment and erosion characterization study for Big Creek Watershed existing conditions with the use of the watershed modeling tools Soil and Water Assessment Tool (SWAT) and Annualized AGricultural Non-Point Source pollution modeling (AnnAGNPS)

- Develop existing condition water budget models for the Big Creek Watershed and Big Creek Marsh for use when developing the water management plan in the next stages of the study

In addition to the above objectives for the water budget analysis and non-point source pollutant loading assessment, the following two objectives were also addressed:

- Investigation of various marsh succession management scenarios, viz., openwater, hemi-marsh and overgrown conditions, during dry, average and wet years under different Lake Erie levels

- Investigation of the effect of variability in precipitation and streamflow conditions on the Big Creek Marsh water budget and marsh succession conditions

Scope of the Study

The quantification of water resources in the watershed is of paramount importance in developing the water management plan. To this end, a Geographical Information System (GIS) based continuous simulation model, Soil and Water Assessment Tool (SWAT), was used to develop an understanding of the water budget components of the Big Creek Watershed. MOE (2006) states that a water budget is an understanding and accounting of the movement of water and the uses of water over time, on, through, and below the surface of the earth. The outputs from the SWAT model provide information by generating estimates of various water budget components, such as streamflow, evapotranspiration (ET), baseflow and tile flow.

At the outlet of the Big Creek Watershed is located a significant wetland. A spreadsheet-based model was developed to provide water budget component estimates of the Big Creek Marsh, including the inflows and outflows to and from the marsh. A rigorous understanding of the water budget will help in evaluating the impacts on the flora and fauna of the watershed. This study will also evaluate the sensitivity of the hydrological components to changes in climate and land use within the watershed.

This report also provides information regarding water quality existing conditions as it pertains to sediment and nutrient loadings. In order to characterize the watershed's contributing sediment and nutrient loadings, a continuous agricultural non-point source pollution simulation model, AnnAGNPS, was used. Spatial and temporal distribution sediment and nutrient estimates are developed for the current watershed conditions. In subsequent stages of the Big Creek Watershed water management plan, future scenarios may then be considered with the developed model to manage the watershed in an optimal manner.

Analysis Tools

The quantification of water resources in the watershed is of paramount importance in developing the water management plan. The spatial and temporal variation in water availability is determined through the help of some of the sophisticated models. A Geographical Information System (GIS) based continuous simulation model called the Soil and Water Assessment Tool (SWAT) was used to develop an understanding of the water budget components of the Big Creek Watershed. A spreadsheet-based model was developed to provide water budget component estimates of the Big Creek Marsh, including the inflows and outflows to and from the marsh. In order to characterize the watershed's contributing sediment and nutrient loadings, a continuous agricultural non-point source pollution simulation model, AnnAGNPS, was used. Analysis of the model results has provided a better understanding of the water management components of this watershed.

SWAT Modeling

The SWAT model was used to describe the hydrologic components of the watershed. A total of 40 subwatersheds were delineated over a study period of 20 years (1990 to 2009). The model was populated with model parameters used in a similar modeling exercise of the adjacent Canard River Watershed, and observed streamflow at a temporary flow monitoring station within the Big Creek Watershed was used to ensure the model development was acceptable.

Marsh Water Budget Modeling

Big Creek Marsh is a riparian wetland in Essex County and is primarily fed by streamflow from the greater Big Creek Watershed. The marsh is approximately 682 hectares in area and is located east of the Detroit River and north of Lake Erie. The wetland in the Big Creek Watershed was investigated in detail using a spreadsheet for water budget analysis with a daily time step. For the development of a water management plan for the Big Creek marsh, a WB model has been developed using a series of 10 input parameters, including. The input model parameters include precipitation, streamflow from the watershed and inputs from Lake Erie (inflow pumping, seepage in through the barrier beach and overflow over the gate outlet). The outflow components include ET, gate outflow, outflow pumping, seepage out through the barrier beach and gate overflow. The marsh was studied over a 40 year period from 1969 to 2008.

The operation of this wetland over this period of time has been split into three operation periods, including the historic management period (1969 to 1984), the carp farm period (1985 to 1999) and the current management period (2000 to 2008). The historical period attempted to maintain a target water level with the use of a dyke and control system in disrepair. The carp farm period attempted to maintain a higher water level by maintaining a closed outlet gate. The current management period followed an MOE PTTW which had three target water levels, including a high (overgrown), medium (hemi) and low (open water) operation plan. The majority of the data available for the first two periods is anecdotal information as records were not maintained or unavailable. Though there generally is a lack of information about the specific operations over all three management periods, there is some recorded information available from 2006 to 2008 and anecdotal information available for the remaining years. During the historic management period, anecdotal information suggests that the operators attempted to manage the wetland in a similar fashion to the current management period, but was unable to be as effective due to a poorly maintained dyke and outlet system. For the carp farm period, the water levels were maintained as high as possible according to anecdotal information, likely to maximize the available fish habitat space. For this time period, it was assumed that the dyke system was repaired and no gate release or outflow pumping was allowed. The current management period has the marsh managed according to a specific management plan as provided to the MOE as part of a 2007 PTTW application. From this application, three potential annual water level operation plans were submitted: Overgrown, hemi and open water. These three operation plans have varied target water levels at different times of the year, and generally consist of a high, medium and low water level operation. Other tools available for wetland operators include the outflow gate and in and outflow pumping.

For the final period, the information available includes inflow pumping data for the years 2006 to 2008 and anecdotal marsh water level information for 2005. Based on this information, the WB model was tested and refined to ensure an acceptable model was developed. A sensitivity analysis was conducted on streamflow, potential ET and hydraulic conductivity to ensure the input parameters affect the appropriate output results. All three parameters considered indicated that the model is acceptable.

Since very little recorded data pertaining to the wetland is available, model calibration and validation is not possible. However, to ensure the marsh components are being estimated in a reasonably accurate way, the model was tested against a series of years with partial information. The drought conditions experienced in 2005 is a recent extreme event that ERCA staff has a great deal of anecdotal information about, while the MOE PTTW database contains inflow pumping data for the years 2006 to 2008. Comparisons of marsh water budget model results with the observed/recorded data from these test years show that the model development is acceptable. Another model check was performed using sensitivity analysis, which also indicated an acceptable model.

Non-Point Source Pollutant Loading Modeling

The AnnAGNPS model provides sediment, nitrogen and phosphorus non-point source loading results at a daily time step. In order to get the variations in loadings of these constituents at different locations of the watershed, the watershed was discretized into a total of 660 cells. The model was simulated over a study period of 20 years (1990 to 2009). Since there is a lack of data available for validation and calibration of this model, hydrologic parameters were compared with the SWAT model to ensure the model development was acceptable.

Study Findings

Hydrological Modeling – SWAT Results

The model results show that the annual WB analysis for the 20 year period of 1990 to 2009 indicates that about 65% of the annual precipitation is lost by ET, with the remaining 35% contributing to the streamflow at 25%, 8% and 2% for runoff, tile drainage and groundwater, respectively. The average annual precipitation is 907 mm. The average annual water yield for the watershed is 306 mm, and annual water yield varies from 163 mm to 512 mm with a standard deviation of 89 mm. Within the different subwatersheds, the average annual ET varies between 560 mm and 692 mm, and the average annual water yield ranges between 206 mm and 351 mm. The other hydrologic components include surface runoff (water yield), tile drainage flow and groundwater flow at 224 mm, 69 mm and 14 mm, respectively (25%, 8% and 2% of annual precipitation, respectively).

Average seasonal analysis indicates that precipitation is higher than ET and water yield combined in the winter, spring and fall. During the summer period, precipitation is less than ET and water yield combined, which indicates soil moisture generally depletes during the summer season. This depletion is normally replenished during the following fall season with the precipitation in excess of ET and water yield. From the seasonal WB analysis, the higher average water yield of 155 mm is observed during the winter season (December to March), which is approximately 51% of the annual water yield. The higher average values of seasonal ET occur during the summer season (June to September) at about 337 mm (57% of the average annual ET). The high ET rates during this season results in a lower average water yield of 55 mm (18% of annual the annual yield).

Results were also generated for the average monthly water budget. Average monthly precipitation for the study watershed varied from 59 mm to 91 mm, with higher precipitations of above 80 mm during the months of April, May, August and September. The lowest average precipitation of 59 mm occurs in February. Higher ET rates are found in June, July and August, with the maximum value at 121 mm in July. Lower average ET values of below 20 mm are found in December, January and February. Monthly average streamflow analysis shows that streamflow varied between 2.5 m^3/s and 3.1 m^3/s as high values during some years. A number of streamflow values were also found to be less than 0.01 m^3/s over the study period, which indicates that this watershed frequently experiences very low flow to dry conditions in certain years. The lowest monthly flow occurred in the year 2005. Higher surface runoff volumes above 35 mm are found in February and March, while lower surface runoff volumes ranging between 6 mm and 11 mm are found during the months of July to November.

From the flow duration curve, monthly simulated streamflow into the marsh that equaled or exceeded 95% of the time is 0.014 m^3/s. Other flow indices of Q90, Q50, Q10 and Q5 are 0.024 m^3/s, 0.545 m^3/s, 1.556 m^3/s and 2.180 m^3/s, respectively. The minimum monthly flow has historically been observed in July, August, September and October with the occurrence frequency of 4, 3, 6 and 3 times, respectively, over the study period. From the flow frequency analysis using a Log Pearson Type III distribution, July to October are the critical months when very low flow conditions occur in the Big Creek watershed. The Q90 during the low flow months vary between 0.010 m^3/s and 0.015 m^3/s.

Big Creek Marsh Model Results

The results for the historic management period shows that the majority of the marsh water level varied between 174.30 m and 175.20 m, with drier periods (water level below 174.30 m) occurring in 7 years (1969, 1970, 1971, 1977, 1978, 1979 and 1982). The overall period water level average is 174.66 m, with an overall minimum and maximum value of 173.90 m and 175.30 m, respectively. In terms of annual average water budget component values, the main inflow components are streamflow (74%), precipitation (23%), and the main outflow components are gate outflow (49%), overflow over the gate (26%) and ET (24%).

The model results for the carp farm period indicates that the water levels remain higher, primarily varying between 174.80 m and 175.20 m. There were brief dry periods with water levels below 174.80 m during the 5 years of 1988, 1991, 1996, 1998 and 1999, and wetter periods with water levels above 175.20 m during the eight years of 1985, 1986, 1989, 1990, 1993, 1995, 1998 and 1999. It has also been noted that there is some overlap of years with dry and wet periods. The overall period average water level is 174.85 m, with an overall minimum and maximum value of 174.20 m and 175.50 m, respectively. In terms of annual average water budget component values, the main inflow components are streamflow (72%), precipitation (21%), and the main outflow components are overflow over the gate (76%) and ET (23%).

The model for the current management period assumed that the hemi (medium) operation plan was implemented each year as an overall average operation (except for 2005). An open water (low) operation water level was implemented for 2005 based on anecdotally observed low water level information. With the exception of 2005, the water level generally varies between 174.10 m and 174.80 m, with an overall period average water level of 174.40 m. In terms of annual average water budget component values, the main inflow components are streamflow (73%), precipitation (22%), and the main outflow components are gate outflow (73%) and ET (24%).

When considering the entire study period, the two largest inputs into the marsh are streamflow (between 72% and 74%) and precipitation (between 21% and 23%), which indicates that the largest inputs affecting this wetland are linked to the natural hydrologic cycle. The higher outputs largely depend on the management period, as gate outflow is the largest parameter for the historic and current management period (49% and 74%, respectively), however this tool is not available for the carp farm period. The most common output parameter among all operation periods is ET, which varies between 23% and 24%.

The year 2005 was a drier year within the study period, and the anecdotal information suggests that the wetland had minimal water for an extended period of time. Since more is known about the water levels during this year, the assumption of a hemi (medium) water management operation was not applied as it was for the other years of this management period. The model was also able to show that had the medium operation rules been implemented, the target water levels would likely have been achieved. Due to the lack of marsh inputs in 2005, this would have resulted in significant inflow pumping to achieve the targets. With the lowest elevation in the marsh being 173.7 m, the maximum and minimum values represent an estimated depth of 1.8 m and 0.0 m, respectively. The year 2005 represents the year when the marsh reaches its lowest water level and is effectively dry for a total of 88 days. Additional investigations of the WB model indicates that had inflow pumping been executed per the MOE PTTW, the medium and low target water levels could have been achieved and maintained.

The connection between Lake Erie and the Big Creek Marsh was also investigated. Over the 40 year study period, the marsh water level was higher than the lake water level the majority of the time (93%). It was also determined that there is a correlation between higher marsh water levels and lake water levels. There are also indications that during lower lake water levels, the wetland would experience a natural drawdown period if not artificially maintained with the outlet control gate and dyke system.

AnnAGNPS Model Results

AnnAGNPS model has been successfully implemented to predict runoff, sediment loading and nutrient loading. Based on the AnnAGNPS modeling results on streamflow, sediment and nutrient loadings, the corresponding maps on the spatial distributions are prepared. The streamflow/runoff value accounts for both surface and subsurface (quick return) components. The average runoff in each cell ranged from 88 mm to 272 mm. The runoff rates were higher in the northeast and along the watershed boundaries, which due to higher slopes at these locations. The maximum and minimum modelled daily flows of the 20 year study period are 30.9 m^3/s and 0 m^3/s, respectively, with an average daily flow rate of 0.47 m^3/s. The sheet and rill erosion are considered in the model and the erosion rates are calculated using RULSE. Clay is the largest contributor to sediment with loadings at 49% of the total yield, which is expected since the watershed is composed primarily of clayey soils and the deposition rate of clay is the smallest. Sediment loading results show that material eroded three soil types, including clay (49%), silt (42%) and sand (9%). The average watershed sediment yield is 0.974 Mg/ha/yr, with higher sediment erosion contributions from the north-west and south-east regions of the Big Creek Watershed. The maximum and minimum modelled daily flows are 2,153 Mg/day and 0 Mg/day, respectively, with an average of 8.3

Mg/day. The months of April, May and June have the highest average monthly sediment yield rates, which is likely caused by spring runoff events.

For nitrogen, the average annual yield for the watershed is approximately 17.1 kg/ha/yr, with a minimum cell value of 0 kg/ha/yr and maximum cell value of 60 kg/ha/yr, most of which comes from the south-east. The months of March, April and May have the highest monthly average total nitrogen yield. The average annual phosphorus yield for the entire watershed is 11.4 kg/ha/yr, with a minimum cell value of 0 kg/ha/yr and maximum cell value of 81 kg/ha/yr, most of which comes from the south-east. The months of April, May and June have the highest monthly average total phosphorus yield.

The cells with the lowest average annual phosphorus and nitrogen yields in the watershed have the land use types of forest and open water. The maximum and minimum modelled daily total nitrogen flows are approximately 15,300 kg/day and 0 Mg/day, respectively. The maximum and minimum modelled daily total phosphorus flows are approximately 15,300 kg/day and 23,000 Mg/day, respectively. The average daily mass flow of nitrogen and phosphorus from the Big Creek Watershed are 207 kg/day and 112 kg/day, respectively.

Big Creek Marsh Management Operations Analysis

In order to conserve diverse aquatic plant species and adequately manage the Big Creek Marsh, an Operations Plan has been developed that includes four schedules for different marsh phases to maintain desired wetland water depths. The marsh phases are categorized as Open water, Hemi and Overgrown phases. There are two schedules of target water depths for the Open water marsh phase and the other two schedules are for the Hemi and Overgrown marsh phases. The operation schedules have specific target water levels for different months over a year. The open water marsh phase is basically low water level marsh while medium and high water levels are maintained in Hemi and Overgrown marsh phases, respectively. A cycle of Open water, Hemi and Overgrown marsh phases includes several years depending upon wetland vegetation types, prevailing marsh hydrology and marsh management. To promote growth and development of new species of vegetation, low water levels are maintained in the Open water marsh phase whereas high water levels are maintained during the Overgrown phase of marsh for removing some of the unwanted vegetation species by inundation. The Hemi marsh phase with medium water levels is maintained for a longer period of time than the Open water and Overgrown marsh phases. This is the most productive phase that supports development of a wide range of plant species in a marsh.

A Water Budget (WB) model has been developed for the Big Creek Marsh to facilitate in operational management of the marsh. There are a controlled gate and a pumping facility to take water into or out of the marsh for regulating water levels at the Big Creek marsh. The developed WB model was utilized in this study to understand how the Big Creek Operations Plan could be implemented to achieve the target water depths for different marsh phases. Accordingly, the WB model was employed to attain the planned target water levels based on the past hydrological conditions of the marsh and the Lake Erie water levels. The model was applied for each individual marsh phases for 40-year period from 1969 to 2008 rather than considering all three marsh phases in a cyclic order because it was intended to look into the suitable hydrological conditions as well as limitations to maintain target water levels for different marsh phases.

Model Considerations and Assumptions

In the application of the WB model, some considerations and assumptions were made focussing on the developed marsh operations plan. Reasonable tolerances with the target marsh levels have been considered for releasing water through gate and water pumping to avoid frequent water taking into the marsh and out of the marsh. Water pumping was limited for the particular months as suggested in the operations plan for different marsh phases. There was no provision of pumping out of the marsh when the lake level was high enough to reach at ridge level along the shore. The daily pumping volume was limited by the existing water taking permit. The specific considerations and assumptions for WB model application are provided below:

- Marsh is operated based on the target levels provided in Table 1 according to the Marsh Operations Plan
- Water is released from the marsh through gate when the marsh level goes above the target level by 0.05m (tolerance level)
- Water is taken out of the marsh by pumping while marsh level exceeds the specified elevation as provided in Table 2 for the selected months during different marsh phases
- Water is pumped out of the marsh when the lake level is higher than the marsh level as well as when the marsh head causing flow to the lake is less than 0.05m
- No pumping is done during high stage of the lake that means when the lake level goes above 174.60m
- Water is taken into the marsh through pumping or gravity flow (when lake stage is higher than marsh stage) during the selected months under different marsh phases as provided in Table 3
- Water is taken into the marsh when the elevation goes below the target level by 0.05m (tolerance level)
- Water is pumped into the marsh when the marsh level is higher than the lake level as well as when the lake head causing flow into the marsh is less than 0.05m
- Pumping is rate is assumed as 88,370 m^3/day according to the PTTW permit

Table 1: Target marsh depths (m) above basin elevation of 173.80m GSC for different marsh conditions

Month	Marsh Phase			
	Open water	**Open water 2**	**Hemi**	**Overgrown**
Jan	0.19	0.30	0.44	0.57
Feb	0.18	0.30	0.44	0.57
Mar	0.26	0.30	0.44	0.60
Apr	0.30	0.30	0.44	0.65
May	0.20	0.30	0.50	0.70
Jun	0.00	0.33	0.57	0.75
Jul	0.00	0.36	0.57	0.80
Aug	0.10	0.39	0.57	0.80
Sep	0.20	0.43	0.57	0.70
Oct	0.30	0.44	0.57	0.60
Nov	0.30	0.44	0.57	0.57
Dec	0.30	0.44	0.57	0.57

Table 2: Provision of water taking out of the marsh by pumping while marsh level exceeds the specified elevation (m) during the selected months for different marsh conditions

Month	Marsh Phase			
	Open water	**Open water 2**	**Hemi**	**Overgrown**
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	>174.15	>174.15	>174.29	>174.60
May	>174.05	>174.15	>174.35	>174.60
Jun	>173.85	>174.23	>174.47	>174.60
Jul	>173.85	>174.26	>174.47	>174.60
Aug	>174.00	>174.29	>174.47	>174.60
Sep	>174.10	>174.33	>174.47	>174.60
Oct	>174.20	>174.34	>174.47	>174.60
Nov	-	-	-	-
Dec	-	-	-	-

Table 3: Provisions of water taking into the marsh by pumping or gravity flow from the lake during the selected months for different marsh conditions

Month	Marsh Phase			
	Open Water	**Open Water 2**	**Hemi**	**Overgrown**
Jan				
Feb				
Mar				
Apr				
May				X
Jun			X	X
Jul			X	X
Aug			X	X
Sep		X	X	
Oct	X	X		
Nov				
Dec				

Weather and Hydrometric Data

Daily precipitation is the main weather variable that is directly utilized as an input of the model. The daily average precipitation data from two climate stations at Amherstburg and Harrow were used in the marsh water balance (Figure 1). Evapotranspiration is one of the water loss processes from the marsh, which was calculated by using the FAO 56 Penman-Monteith method from the weather variables, i.e. temperature, precipitation, and relative humidity and sunshine hours. The daily streamflows entering into the marsh were estimated by the SWAT model. The daily actual Lake Erie water level data recorded at Bar Point were used in the model, and the data were obtained from the from the Environment Canada hydrometric data website.

From marsh operation point of view, precipitation and streamflow during May to October are critical. Therefore, precipitation and streamflow data for these seven months over the period, 1969 to 2008 were analyzed to select the representative years for dry, average and wet hydrologic conditions. Table 4 presents the common dry, average and wet years based on both precipitation depth and streamflow volume, and the table also shows the percent ranks corresponding to the precipitation and streamflow amount in the specific year.

Table 4: Selected dry, average and wet years based precipitation and streamflow during the months May to October

Hydrologic Condition	Year	Precipitation		Streamflow	
		Depth (mm)	**Percent rank**	**Volume (m^3)**	**Percent rank**
Dry year	2005	273	0%	1407772	5%
	1999	290	5%	514016	0%
	1982	322	13%	1856169	8%
Average year	2007	479	49%	5991071	46%
	2001	479	51%	7431766	59%
	1973	481	54%	6918614	49%
Wet year	1986	693	97%	12066541	85%
	1981	730	100%	21671580	100%
	1969	661	95%	18755424	97%

Lake Erie level has a great influence in maintaining required water depths in the Big Creek marsh. A higher lake level than the marsh level prevents from lowering the marsh depth by gravity drainage through the gate. The daily lake level data over the period 1969 to 2008 were analyzed to look into the higher lake level above176.6m. The number of days that the lake level was above 174.60m during 1969 to 2008 and the monthly average lake levels during that time period are shown in Figures 37, 38, 39, and 40. It is evident from the table that lake levels were substantially higher in 14 out of 40 years.

Marsh Levels in Different Hydrologic Conditions

This section provides results of the simulated daily marsh levels along with actual lake levels and target levels of the particular marsh scenario as well as daily streamflow entered into the marsh, water released from the marsh and lake water taken into the marsh through the gate, and water pumped into and out of the marsh under different hydrological conditions. Based on the precipitation depth and streamflow quantity during May to October over the period 1969 to 2008, three natures of hydrologic conditions, i.e. dry year, average year and wet year conditions were selected (Table 4) to present the results. Three representative years under each nature of hydrologic conditions were chosen to look into the effect of the variations in precipitation, eventually streamflow, and lake levels on maintaining required marsh depths for a particular marsh phase. The selected years for dry year condition are 2005, 1999 and 1982, the average years are 2007, 2001 and 1973, and the wet years are 1986, 1981 and 1969. The results are presented in graphical form for detailed understanding about the simulated marsh depths for different marsh scenarios that are presented in the following subsections.

Open Water Marsh Scenario

The model simulated daily marsh levels for the Open Water Marsh scenario under a dry year condition, 2005 is shown in Figure 1. As the lake levels were mostly higher than the marsh levels from the mid April to the end of September, 2005, water was pumped out initially for about a month to lower down the marsh level to required depths. There was only significant streamflow at the end of July over the period mid May to mid November, and hence, the marsh levels remained almost below the target levels. Some water from the lake was taken into the marsh but the gate and pumping in October, which is the only month for taking water into the marsh according to the operations plan for the Open Water Marsh. The marsh levels pattern as shown in Figure 2 for 1999 dry year condition is similar to that in 2005 condition. There was no significant streamflow even in the month of November and December, 1999, and the marsh levels were found very close to the target levels during this period. In the dry year, 1982, marsh levels (Figure 3) were much higher than the target levels because of very high lake stage during mid March to mid July when there was no substantial release of water from the marsh by the gate. Moreover, there is no provision of pumping water out of the marsh while lake level is higher than 174.6m according to the operations plan, as the water level reaches to the ridge level at this stage of lake.

Daily marsh levels under the average year, 2001 condition for the Open Water Marsh scenario is presented in Figure 4. It appears from the figure that the amount water released from the gate was not enough due to low head during April to mid June, 2007. The pumping for taking out water from the marsh was also limited for couple of days. As a result, marsh level remained far above during May to mid June. In case of 2001 average year condition, marsh levels were reasonably close to the target levels (Figure 5). During the average year, 1973, the marsh levels were found very close to the lake levels and so, a small quantity of water drained out from the marsh through the gate (Figure 6). Since the lake level was above 174.6 m during mid March to August, 1973, there was no pumping in this period. Consequently, the marsh levels remained much above the target level.

In a wet year condition of 1986, marsh levels were found far above the target levels because of high lake stage, substantial streamflow into the marsh, and low outflow of water from the marsh (Figure 7). It is revealed from Figure 8 that lake levels were mostly higher than the marsh levels in May to August that impeded the drainage from the marsh by the gate during this period. There were high streamflow during September and October. As a result, the marsh levels were highly above the target levels during most of the time of average year, 1981 although water was pumped out of the marsh for about 110 days with limited capacity of 88,370m^3/day. Figure 9 also indicate that in a wet year condition like in 1969, it is difficult to maintain low marsh levels as required for the Open Water Marsh phase because of high volume of streamflow entering in to the marsh.

Open Water 2 Marsh Scenario

Marsh elevations under dry year conditions for the Open Water 2 Marsh scenario are shown in Figure 10, 11 and 12. The pattern of marsh levels in dry years 2005 (Figure 10) and 1999 (Figure 11) were mostly similar. During June to September, the levels were below the target levels as there was no significant streamflow and water pumped into the marsh in this period. Then the levels reached close to the target levels with water taking from the lake by the gate and pumping in the month of September and October. Figure 12 depicts that the marsh levels were considerably above the target levels until middle of July, 1982. The high stages of marsh level during mid April to mid July were due to high lake levels, above 174.6m when pumping out of the marsh was not considered according to the operations plan.

Under average year conditions, model simulated marsh levels for Open Water 2 Marsh Scenario are provided in Figure 13, 14 and 15. It is evident from Figure 13 that the levels were above the target levels until middle of June, 2007 due to considerable amount of streamflow into the marsh, low drainage rate from 2nd week of April to mid June and limited days of water pumping out of the marsh. The marsh level decreased below the target level in July because of evapotranspiration loss from the marsh and increased above the target level in the middle of August with the incoming streamflows. In the average year 2001, the marsh levels were found close to the target levels in most of the time except in July, August and early September. The marsh level sufficiently decreased in the summer months as there was no significant streamflow and evapotranspiration loss was higher in these months. Figure 15 shows that the marsh levels were considerably above the target levels in 1973 because of high lake stage, available low head for draining water out of the marsh, and limitations in water pumping from the marsh when lake level goes above 174.6m.

The daily simulated marsh levels for Open Water 2 Marsh Scenario in wet year condition are shown in Figure 16, 17 and 18. In the wet year condition of 1986 (Figure 16), the marsh levels remained far above the target levels as the lake levels were high enough that limited the drainage of water through gate. Moreover, water pumping from the marsh was not considered since lake levels were higher than 174.6m. In 1981 wet year condition (Figure 17), low marsh head and high lake elevation during April to August, and large streamflow volume resulted in considerably higher marsh levels than the target levels in spite of water taken out of the marsh by pumping. Figure 18 shows that very high streamflow during March to August and limited drainage from the marsh were responsible for the high marsh levels in wet year 1969.

Hemi Marsh Scenario

The simulated marsh elevations under dry year condition for Hemi Marsh phase are depicted in Figure 19, 20 and 21. In order to maintain medium water depths for the Hemi Marsh, it was required to take water into the marsh for considerable number of days during June to September in dry years 2005 (Figure 19) and 1999 (Figure 20). The attained marsh levels were found very close to the target levels during the months May to December in both years. In dry year 1982, the water discharged from the marsh by the gate was insignificant. As the lake levels were above 174.6m during mid April to mid July, 1982 (Figure 21), there was no consideration to take water out of the marsh by pumping. Hence, the marsh levels remained high above the target levels until end of July.

In the average year condition of 2007, the required water depths for the Hemi Marsh were fairly maintained by water pumping out of the marsh for few days in April and water pumping into the marsh for some days in summer months (Figure 22). The marsh depths were well maintained to target levels in the average year 2001 by pumping water into the marsh for 22 days during June to September (Figure 23). It appear from Figure 24 that the marsh levels remained mostly high above the target level due to high lake stage and low release of water from the marsh in the average year 1973.

Based on the wet year condition of 1986, the simulated marsh levels were found far above the target levels and close to the lake levels (Figure 25). As the lake levels were very high and above 174.6m, there was no pumping to take water out of the marsh. The release of large volume of incoming streamflow by the gate was also limited due to very low marsh head. Hence, the marsh stage became very high. Figure 26 presents the marsh elevations under wet year condition of 1981. It is revealed from the figure that water was pumped out from the marsh during May, and marsh level reached to the target level at the end of May. Afterwards, the marsh levels increased above the target levels due to high streamflow as well as high precipitation. The simulated marsh levels under the wet year condition of 1963 were mostly far above the target level (Figure 27) because of very high streamflow and precipitation that occurred frequently in the spring and summer.

Overgrown Marsh Scenario

The model results for Overgrown Marsh Scenario under dry year condition are presented in Figure 28, 29 and 30. The results of three dry years, 2005, 1999 and 1982 indicate that the target high water stages for the overgrown marsh could be achieved by pumping water into the marsh during May to August with the pump capacity of capacity of 88,370m3/day. The number of pumping days varied on the severity of the hydrologic drought condition in different years.

The marsh levels for the average year condition in 2007, 2001 and 1973 are provided in Figure 31, 32 and 33 respectively. Under the average condition of 2007, the marsh levels were mostly maintained to the target levels by pumping water into the marsh from the lake for few days (Figure 31). In the year 2001, lake water was pumped into the marsh for several days in the months of May to August (Figure 32) and the marsh levels were well maintained to the target levels. Figure 33 shows that the very high lake stage and low marsh head in the average year 1973 were the main reasons for the high marsh levels above the target levels.

Figure 34 depicts the daily simulated marsh levels under a wet year condition of 1986 for the Overgrown Marsh scenario. In this year, the marsh levels were found considerably above the target levels because of very high stage of lake, large volume of streamflow entered into the marsh, and small volume of water released from the marsh. The model simulated marsh levels for the wet year 1981 is shown in Figure 35. It appears from the figure that the marsh level widely fluctuated with the high streamflow events, and it remained above the target levels throughout the year except for some days in the spring. Figure 36 presents the simulated marsh levels under the wet year condition of 1969. The marsh levels were found mostly above the target levels and varying with the large streamflow events over the year.

Simulated and Target Marsh Levels

The model simulated monthly average marsh level and the corresponding target level for the different marsh scenarios together with the lake level over the 40-year period from 1969 to 2008 are presented in this section. The numbers of days that the daily marsh level found within the certain limits (±0.10m, ±0.15m and ±0.20m) from target level in different months of the years are also provided in this section. In order to evaluate that how long and how close the simulated marsh level was to the target level, percentage of time was calculated as the total number of days that the marsh level remained within the specific limit during the critical period (April to October) divided by the total days (214) in the critical months. The results are provided according to different marsh scenarios.

Open Water Marsh Levels

Figure 37 presents monthly average simulated marsh level and target marsh level for open water marsh, and lake level over the period 1969 to 2008. The figure shows that the lake level has great influence to attain low water levels for the Open Water Marsh phase because high lake stage causes low or nil drainage flow from the marsh through the gate. The figure indicates that monthly average marsh level fluctuated with the lake levels. Thus, the marsh level was found close to the target level only in few years when lake stage was low. It is also evident from the figure that there was a cyclic pattern in the occurrence of very low and very high lake levels before 1999 with irregular intervals of a number of years, and relatively low lake levels were observed continuously from 1999 to onwards.

The numbers of days that the marsh level found within in ±0.10m, ±0.15m and ±0.20m limit from the target level are presented in Table 7, 8 and 9 respectively. The cells of the table are highlighted when the numbers exceed 15 days in a month during the critical period April to October. The table cells are also highlighted for the values greater than or equal to 50% time that the marsh level remained within the specified range. Table 7 shows that the marsh elevations were within ±0.10m range from the target level for over 50% time during the critical period in 1970, 1971, 1988, 1999, 2000, 2001, 2003 and 2006, but the marsh level was found outside the limit for more than 15 days in each of two or more consecutive months of 1970, 1988, 1999, 2000, 2003 and 2006.

Open Water 2 Marsh Levels

The model simulated monthly average marsh level for the Open Water 2 Marsh scenario together with the target marsh level and lake level over the period 1969 to 2008 are shown in Figure 38. The Open Water 2 Marsh scenario also considers low water depth marsh, and the results are mostly similar to that for the Open Water Marsh scenario as discussed in the earlier subsection.
Table 10, 11 and 12 provides the numbers of days that the marsh level remained within the range respectively, ±0.10m, ±0.15m and ±0.20m from the target level, and the percent time that the level was within the specified limit. Based on ±0.10m limit, the marsh level was found close to the target level for over 50% time during the critical period in 1970, 1977, 1994, 1995, 2000, 2001, 2002, 2003 and 2006. Nevertheless, the marsh level was found beyond the limit for more than 15 days in each of two or more successive months in 1977, 1994, 2001, 2002 and 2003 among the above mentioned years.

Hemi Marsh Levels

Figure 39 shows the monthly average of the simulated daily marsh levels for the Hemi Marsh scenario, target levels and lake levels for 40-year period from 1969 to 2008. The figure indicates that the marsh level was found close to the target level in about 20 years with 10 successive years from 1999 to 2008. Table 13, 14 and 15 presents the numbers of days that the marsh level found within the limit of ±0.10m, ±0.15m and ±0.20m respectively from the target level in different months over the years 1969 to 2008. The marsh stage was found within ±0.10m limit from the target level for more than 50% time during the critical period in 1970 to 1972, 1977, 1978, 1988, 1991, 1994, 1995 and 1999 to 2008. Based on ±0.20m limit, the level was found within the limit for over 50% time of the critical period in the earlier mentioned years and in some additional years, 1979, 1989, 1990 and1998.

Overgrow Marsh Levels

The monthly average simulated marsh level for the Overgrown Marsh Scenario, target marsh level and lake level over the period 1969 to 2008 are depicted in Figure 40. It appears from the figure that the model simulated marsh level is close to the target level in most of the years except in the some years when the lake level was extremely high. It is also revealed from the figure that the marsh stage was found above the target level in almost every year for the high-stage Overgrown Marsh scenario.

The numbers of days that the simulated marsh level found within in the range of ±0.10m, ±0.15m and ±0.20m from the target level are presented in Table 16, 17 and 18, respectively for the period from 1969 to 2008. The marsh level remained within ±0.10m limit for over 50% time of the critical period in 24 out of 40 years, and the level was found within ±0.20m limit for above time in 30 out of 40 years.

Water Quantities

This section presents the results of selected water budget components that are managed or controlled for maintaining required water depth for different marsh phases. The selected water quantity components are: water released from the marsh by the gate, water pumped into the marsh, water pumped out from the marsh, and water taken into from lake through the gate. The annual results of each of the components for four marsh scenarios under different hydrologic conditions as well as for each individual year from 1969 to 2008 are provided in the following subsection.

Water Released from the Marsh

The water quantity released from the marsh along with the streamflow entered into the marsh in different years from 1969 to 2008 under Open Water, Open Water 2, Hemi and Overgrown Marsh scenarios are shown in Figure 41, 42, 43 and 44, respectively. Table 19 presents the amount of water released from the marsh by the gate and the number of water release days under different hydrologic conditions. In dry year condition of 1999, the lowest amount of water released from the marsh was about 8,253,800 m^3 in 82 days under Open Water Marsh scenario. Water released in the same year from the marsh under Hemi and Overgrown Marsh scenarios were respectively, 9,889,400 m^3 and 10,109,800 m^3 in 75 and 47 days. The quantity of water released under Open Water Marsh scenario is less than that of Hemi and Overgrown Marsh scenarios because substantially more amount was pumped out of the marsh in case of the Open Water scenario than that in the other two scenario. The range of water quantity released under average year condition was from 12,734,600 m^3 to 22,954,800 m^3 and the water release days varied between 54 and 279 for different marsh scenarios. The numbers of water release days are more for Open Water Marsh scenario and less for Overgrown marsh scenario in the average years, 2007 and 2001, while the situation was reverse in the average year 1973 because of mainly high lake stage almost throughout the year. In the wet year condition of 1981 and 1969, the water quantity released from the marsh was found between 18,094,100 m^3 and 26,606,766 m^3 for different marsh scenario. The amount of water released in the wet year 1986 was found same as 8,521,800 m^3 for all four marsh scenario, and the water quantity was significantly low due to very high lake stage exceeding 174.6m throughout the year.

Water Pumped into the Marsh

The amount of water pumped into the marsh and the numbers of pumping days in different years, from 1969 to 2008 under Open Water, open Water 2, Hemi and Overgrown marsh scenarios are depicted in Figure 45, 46, 47 and 48, respectively. The figures show that water was pumped in the frequent years from 1988 to 2008, and in some years before 1988. The pumped water quantity in a particular year under different marsh scenarios varied fro the variations in the target marsh depths as well as due to differences in the number of months for pumping.

Table 20 provides the quantity of water pumped into the marsh and the pumping days in different hydrologic conditions. Under dry year conditions and Open Water Marsh Scenario, the pumped water quantity varied from 176,740 m^3 to 353,480 m^3 with pumping for 2 to 6 days in the month of October only. The water quantity for the Open Water 2 Marsh scenario was found varying from 176,740 m^3 to 1,148,810 m^3 with 2 to 13 days of pumping in September and October. Table 20 indicates that the maximum pumping water quantity was from Hemi Marsh Scenario with the volume of 2,739,470 m^3 and 31 days of pumping under the dry condition of 1999. In the same year, the water quantity for the Overgrown Marsh scenario was found as to 2,474,360 m^3 with 28 days of pumping. Under the average condition, the larger amount of water was found in 2001, and the pumped water volume for Hemi and

Overgrown Marsh Scenarios were respectively, 1,944,140 m^3 and 2,385,990 m^3 with 22 and 27 days of pumping.

Water Pumped out from the Marsh

The quantity of water pumped out of the marsh and the corresponding pumping days in various years over the period 1969 to 2008 under Open Water, Open Water 2, Hemi and Overgrown Marsh scenarios are shown in Figures 49, 50, 51 and 52 respectively. The figures show that, in general, the pumped water quantities were relatively less during the years 1999 to 2008, which are consistent with lower lake stage over this period as more water can be drained out through the gate when lake stage is low. The pumped water quantity for different marsh scenarios varied mainly because of variations in the lake stage with respect to the marsh level, and also due to limitations in pumping when lake level was above 274.6m.

Table 21 provides the amount of water pumped out from the marsh and the pumping days under different hydrologic conditions. As the Open Water Marsh scenario requires maintaining lower marsh depth, relatively higher quantity of pumped water was generally found for this marsh scenario. The highest pumped water volume under dry year condition was found in 2005 for the Open Water Marsh scenario, and the pumped water volume was 3,534,800 m^3 with 40 days of pumping. The maximum amount of pumped water for the Hemi Marsh scenario under dry and average conditions was 1,237,180 m^3 with 14 days of pumping. The pumped water quantity fro the Overgrown Marsh scenario was found as 397,899 m^3 with 6 days of pumping in 1982 only among the selected 9 years of different hydrologic conditions. Although the largest water quantity of 9,897,440 m^3 with 112 days of pumping was computed for the Open Water Marsh scenario under wet year condition of 1981, the marsh level was found far above the target level during most of the time in this year. Hence, it is not feasible to pump water out of the marsh in order to maintain water depth for the Open Water Marsh phase during a wet year.

Water Taken from Lake through Gate

The quantity of water taken from the lake through the gate and the number of days to take water in different years from 1969 to 2008 under Open Water, Open Water 2, hemi and Overgrown Marsh scenarios are shown in Figures 53, 54, 55 and 56 respectively. The figures indicate that water was taken in to the marsh in some years for the few days mostly. The amount of water taken into the marsh varied due to variations in the availability of lake head (differences between the lake and marsh levels) and differences in the months to take water for the different marsh scenarios.

Table 22 presents the amount of water taken from the lake and the corresponding number of days for taking water into the marsh under different hydrologic conditions. Under dry year condition, the maximum water quantity taken for the Open Water Marsh scenario was 530,220 m^3 in 6 days during October while the maximum quantity for the Open Water 2 Marsh scenario was found as 1,148,810 m^3 in 13 days during September and October, 1999. In the case of the Hemi Marsh scenario, the water quantity taken during June to September under the dry and average year conditions varied from 353,480 m^3 (in 4 days) to 2,739,470 m^3 (in 31 days). The table also shows that the amounts of water taken during May to August under the dry and average year conditions for the Overgrown marsh scenario were within the range between 706,960 m^3 (in 8 days) and 2,474,360 m^3 (in 28 days).

Findings and Conclusions

The purpose of the water quantity study is to understand the hydrologic impacts associated with the watershed to a level of detail that will provide an understanding of the need and recommendations for protecting and enhancing water quantity levels throughout the watershed. This information, along with other reports on natural heritage and water quality, has been used for the development of the Big Creek Watershed Plan.

The quantification of water resources in the watershed is of paramount importance in developing the watershed plan. In order to undertake a comprehensive water quantity analysis of this watershed, many tools and methods have been utilized. A water budget was prepared as one of the major components of the water quantity study. This is a mathematical model that assesses and balances water entering, leaving and being stored in a system. In order to develop hydrologic modeling tools, physical data requirements include: topography, soils, and land use and drainage information. As well, climate data including daily precipitation, maximum and minimum temperature, wind speed, relative humidity and solar radiation were necessary model inputs.

A Geographical Information System (GIS) based continuous simulation model called the Soil and Water Assessment Tool (SWAT) was used to develop an understanding of the water budget components of the Big Creek Watershed. A spreadsheet-based model was developed to provide water budget component estimates of the Big Creek watershed, including the significant inflows and outflows. The SWAT model simulated hydrologic water budget results from 1990 to 2009 which have been presented annually, seasonally and in monthly time scales.

In order to characterize the watershed's contributing sediment and nutrient loadings, a continuous agricultural non-point source pollution simulation model, AnnAGNPS, was used. The annual model results show that evapo-transpiration (ET) is the most significant hydrologic factor. The other hydrologic components include surface runoff (water yield), tile drainage flow and groundwater flow. The simulated groundwater flow is relatively low compared to the other hydrologic components, which could be due to a variety of reasons such as major historical watercourse diversions and the existence of tile drainage networks within the Big Creek Watershed. The model results identified that the highest levels of ET are occurring in the northern and southwestern portion of the watershed.

Average seasonal analysis indicates that precipitation is higher than ET and water yield combined in the winter, spring and fall. During the summer period, precipitation is less than ET and water yield combined, which indicates soil moisture generally depletes during the summer season. This depletion is normally replenished during the following fall season with the higher relative precipitation.

Average monthly precipitation for the watershed study varied from 59 mm to 91 mm, with higher precipitations of above 80 mm during the months of April, May, August and September. The lowest average precipitation of 59 mm occurs in February. Higher ET rates are found in June, July and August, with the July average being the maximum value at 121 mm. Lower average ET values of below 20 mm is found in December, January and February. Higher surface runoff volumes above 35 mm are found in

February and March, while lower surface runoff volumes ranging between 6 mm and 11 mm are found during the months of July to November.

Monthly average streamflow analysis shows that high values of streamflow varied between 2.5 m^3/s and 3.1 m^3/s during some years. A number of streamflow values were also found to be less than 0.01 m^3/s over the study period, which indicates that this watershed frequently experiences very low flow conditions in certain years. The lowest monthly flow occurred in the year 2005. These results, along with anecdotal observations, indicate that flow conditions in Big Creek are among the most stressed of Essex Region watersheds. This is likely due, at least in part, to the historic major diversions of headwater areas out of the Big Creek Watershed.

For Big Creek Marsh water budget, inflow and outflow components may include many different components during specific periods of time. The inflow components considered include precipitation, stream flow from the upstream watershed, seepage from Lake Erie into the marsh through the beach ridge along the shore, inflow water pumping from Lake Erie to achieve the desired water level, and flow overtopping the control dam structure from Lake Erie. Outflow components considered for the water budget includes ET, seepage flow to Lake Erie, outflow pumping of the marsh to Lake Erie, outflow to Lake Erie from the control gate, and flow overtopping the control dam structure to Lake Erie. Groundwater inflow and outflow sources excluding Lake Erie are assumed to be zero.

Water levels in the marsh have the ability to be managed, which could include targets as approved in a recent management plan associated with a Ministry of the Environment (MOE) Permit to Take Water (PTTW). The goal of this component of the study was to develop a model that would adequately simulate the marsh operations and reactions to streamflow and climatic changes in order to provide suggestions and recommendations to property owners toward a future management plan.

The water budget was developed using 40 years of data, some of which is recorded and some of which is from anecdotal information and observations. The operation of this wetland over this timeframe varied responding to the financial capabilities of the operators and the intent of the management operations. Though there generally is a lack of information about the specific operations over the management periods, there is some recorded information available from 2006 to 2008 and anecdotal information available for other years. The drought period in 2005 together with the impacts on the water basin were also used as a benchmark reference.

During the initial management period, anecdotal information suggests that the operators attempted to manage the wetland for waterfowl productivity which is similar fashion to the current management period, but were unable to be as effective due to a poorly maintained dyke and control structure (dam). During a period of time in the 1970's until the 1990's, the water levels were maintained as high as possible according to anecdotal information, to provide for operation of a fishery at the lower basin near the current Hunt Club. During this timeframe repairs to the dam structure and the dyke system at the outlet were completed to allow for holding as much water as possible in accordance with the original dam and dyke construction parameters. The current management period has an assumed marsh operation managed according to a specific management plan as provided to the MOE as part of a 2007 PTTW application. From this application, three potential annual water level operation plans were submitted: Overgrown, hemi and open water. These three operation plans have varied target water levels at different times of the year, and generally consist of a high, medium and low water level operation. The main tools available for wetland operators include the outflow gate and in and outflow pumping.

The drought conditions experienced in the entire watershed in 2005 is a recent extreme event that ERCA staff has a great deal of anecdotal information about and the MOE PTTW database contains inflow pumping data for the years 2006 to 2008. Comparisons with the model to these test years show that the model development is acceptable. Another model check was performed using sensitivity analysis, which also indicated an acceptable model.

The results for the historic management period shows that the majority of the marsh water level varied between 174.30 m and 175.20 m, with drier periods (water level below 174.30 m) occurring in 7 years (1969, 1970, 1971, 1977, 1978, 1979 and 1982). The overall period water level average is 174.66 m, with an overall minimum and maximum value of 173.90 m and 175.30 m, respectively. The model results for the carp fishery period indicates that the water levels remained higher, primarily varying between 174.80 m and 175.20 m. There were brief dry periods with water levels below 174.80 m during the 5 years of 1988, 1991, 1996, 1998 and 1999, and wetter periods with water levels above 175.20 m during the 6 years of 1985, 1986, 1989, 1990, 1993, 1995, 1998 and 1999. It has also been noted that there is some overlap of years with dry and wet periods. The overall period average water level is 174.85 m, with an overall minimum and maximum value of 174.20 m and 175.50 m, respectively. The model for the current management period assumed that the hemi (medium) operation plan was generally implemented for most years as an overall average operation. The water level tends to vary between 174.10 m and 174.80 m, with an overall period average water level of 174.40 m.

When considering the entire study period, the two largest inputs into the marsh are streamflow (between 72% and 74%) and precipitation (between 21% and 23%), which indicates that the largest inputs affecting this wetland are linked to the natural hydrologic cycle. The higher outputs largely depend on the management period, as gate outflow is the largest parameter for the historic and current management period (49% and 74%, respectively), however this tool is not available for the timeframe that operating a fishery was the main objective. The most common output parameter among all operation periods is ET, which varies between 23% and 24%.

The connection between Lake Erie and the Big Creek Marsh was also investigated. Over the 40 year period studied as defined previously, the marsh water levels were higher than the lake water level the majority of the time (93%). This was further confirmed through aerial photograph research which compared high and low lake water periods and marsh health. It was further determined that there is a correlation between higher marsh water levels and lake water levels. There are also indications that during lower lake water levels, the wetland would experience a natural drawdown period if not artificially maintained with the outlet control gate and dyke system.

Although the optimal operation of the private dam and portable pumping system may be able to sufficiently augment the water levels in the marsh, it may not be realistic to expect that this will always be feasible during prolonged and/or extreme dry periods in the future when there is little or no inflow from the upstream watershed, combined with substantial loss of water due to ET. In addition, the 40 year timeframe included three significantly high lake level periods during the 70's, the mid 80's and the late 90's. In addition, the Lake Erie water levels measured all time record highs in 1985/86 and again in 1998. This potentially skews results that are not available to our model from earlier periods during record low levels of the lake in the 1930's and the 1960's. Low water extremes are being forecasted for all climate change models so the modelling which has been completed may be representative for the timeframes being modelled but may be inadequate for the future reference due to the higher probability of experiencing lowering lake water levels. In addition climate change models are forecasting extremes in climate variability, which may result in more extreme weather events in the future. It is also important to note that artificially maintained water levels in the marsh do not extend upstream to the middle and upper reaches of the watershed due to historical diversions at the headwaters. These upstream reaches will continue to be highly stressed during drought conditions. Due to major historical diversions of flow out of the headwaters, the natural flow conditions have been highly impacted to a much greater degree than other watercourses in the region.

The Annualized Agricultural Non-point Source (AnnAGNPS) was the computer model which was utilized to simulate the Big Creek Watershed's sediment, nitrogen and phosphorus non-point source loading results at a daily time step. The watershed was divided into a total of 660 cells over a study period of 20 years (1990 to 2009). Since there is a lack of data available for validation and calibration of this model, hydrologic parameters were compared with the SWAT model to ensure the model development was acceptable.

Sediment loading results show that eroded material contained three soil types, including clay (49%), silt (42%) and sand (9%). Clay, as the largest contributor to sediment loading, is to be expected as the watershed is composed primarily of clayey soils and the deposition rate of clay is the slowest. The total average watershed sediment yield is 0.974 Mg/ha/yr, with higher sediment erosion contributions from the north-west and south-east regions of the Big Creek Watershed. The maximum and minimum modelled daily flows are 2,153 Mg/day and 0 Mg/day, respectively, with an average of 8.3 Mg/day. The months of April, May and June have the highest average monthly sediment yield rates, which is likely caused by spring runoff events.

For nitrogen, the average annual yield for the watershed is approximately 17.1 kg/ha/yr, with a minimum cell value of 0 kg/ha/yr and maximum cell value of 60 kg/ha/yr, most of which comes from the south-east. The months of March, April and May have the highest monthly average total nitrogen yield.

Phosphorus is not as mobile as nitrogen, but is strongly absorbed by the soil. Phosphorus that is absorbed by sediment particles may be conveyed in overland flow. The average annual phosphorus yield for the entire watershed is 11.4 kg/ha/yr, with a minimum cell value of 0 kg/ha/yr and maximum cell value of 81 kg/ha/yr, most of which comes from the south-east. The months of April, May and June have the highest monthly average total phosphorus yield.

The findings of the Big Creek Watershed Plan have identified the conditions present during the modelled years. This time step however does not include extreme historic lows of Lake Erie and cannot model the conditions that may have been present with a watershed that at one point in time was three times larger than the current modelled watershed. The uncertainty with climate variability dictates the need to have consideration for extreme caution in managing the water resources available to the Big Creek watershed. The historic methodologies of capturing and directing all storm flows and then out letting as efficiently as possible may well be harmful to a waterway that is in a deficit position relative to water budget. Future planning processes will need to respond to the impacts of climate change and ensure that planning models include considerations for managing or supplementing the watershed inputs available to the system with a goal being to balance the current water budget model.

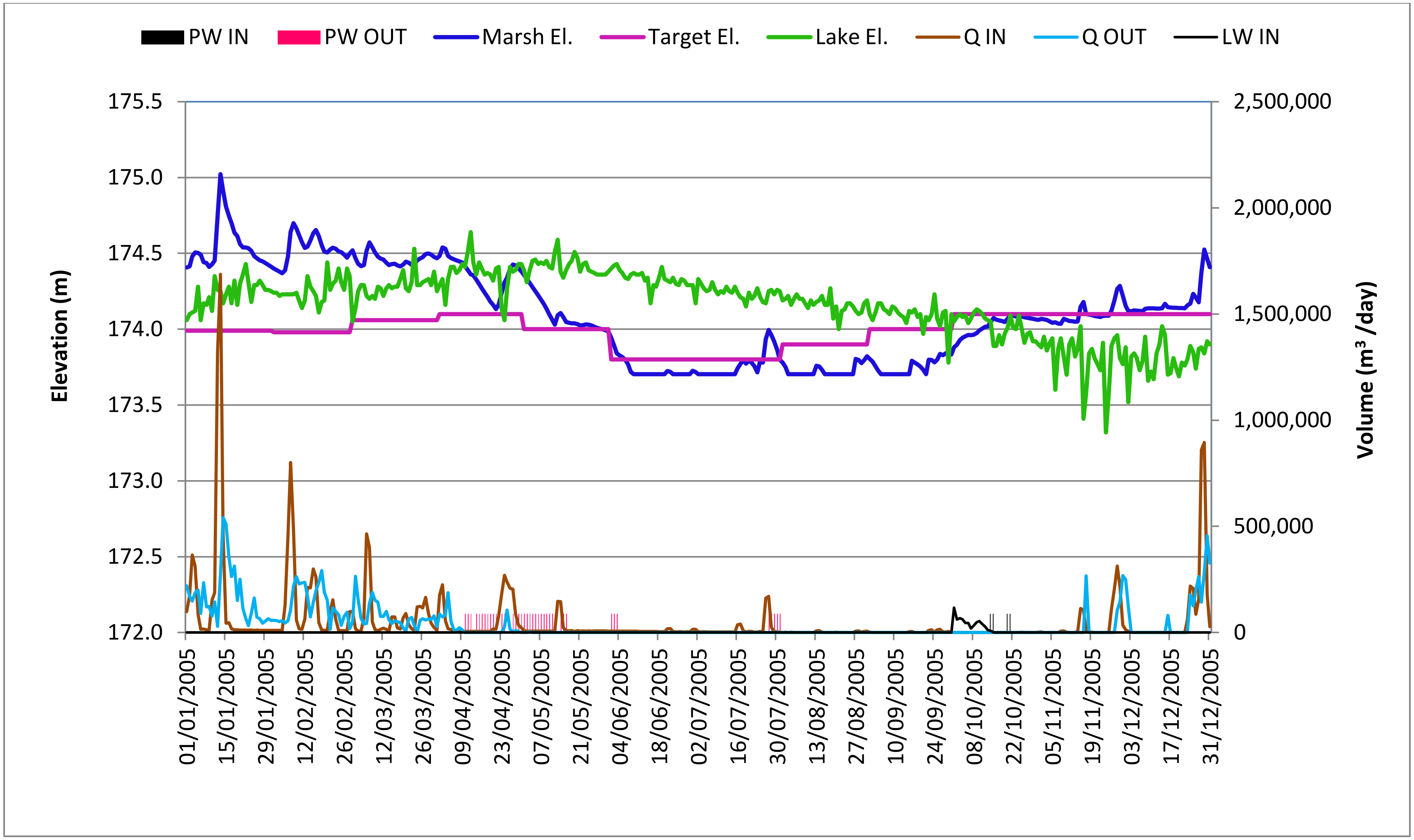


Figure 1: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in a Dry Year, 2005 Condition

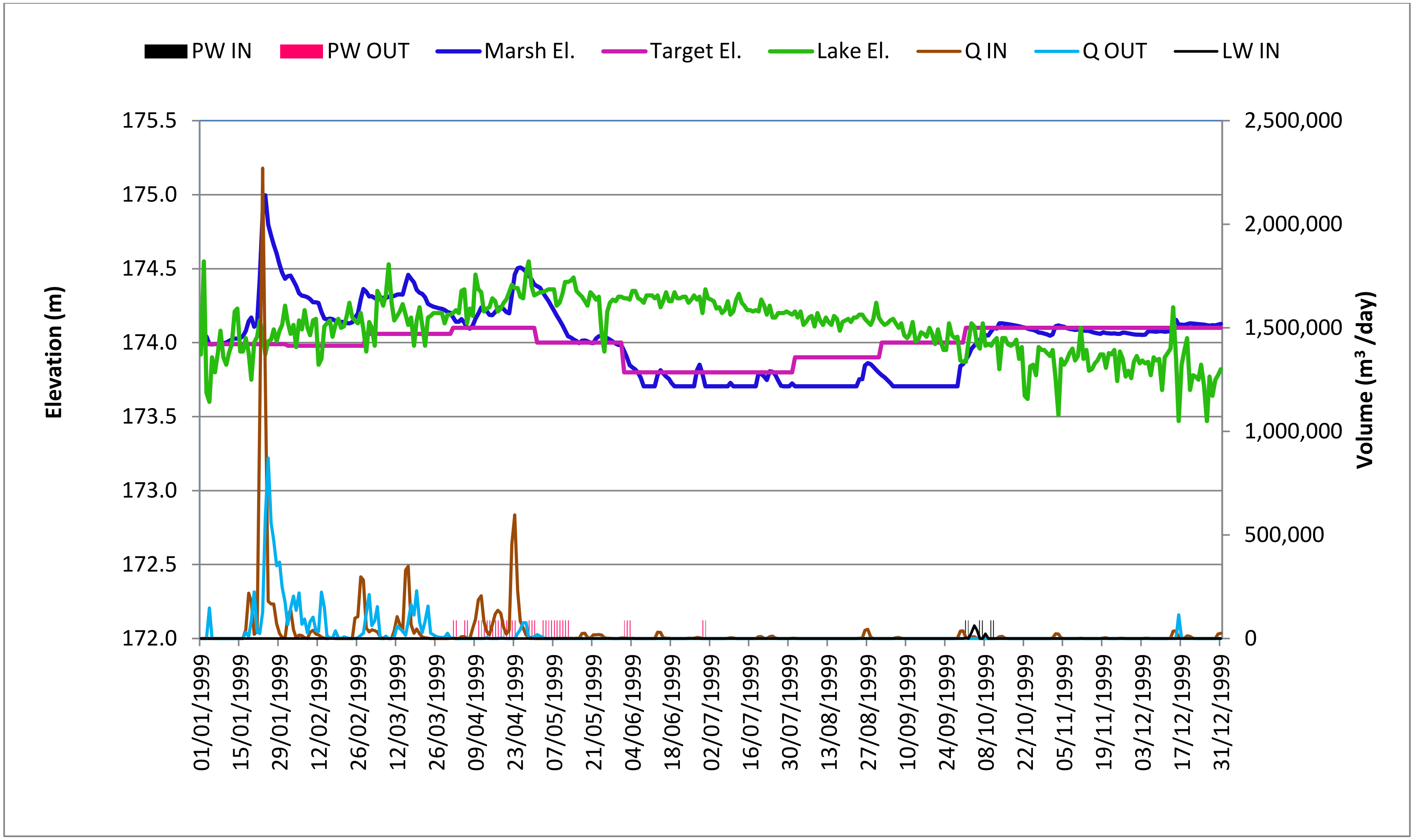


Figure 2: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in a Dry Year, 1999 Condition

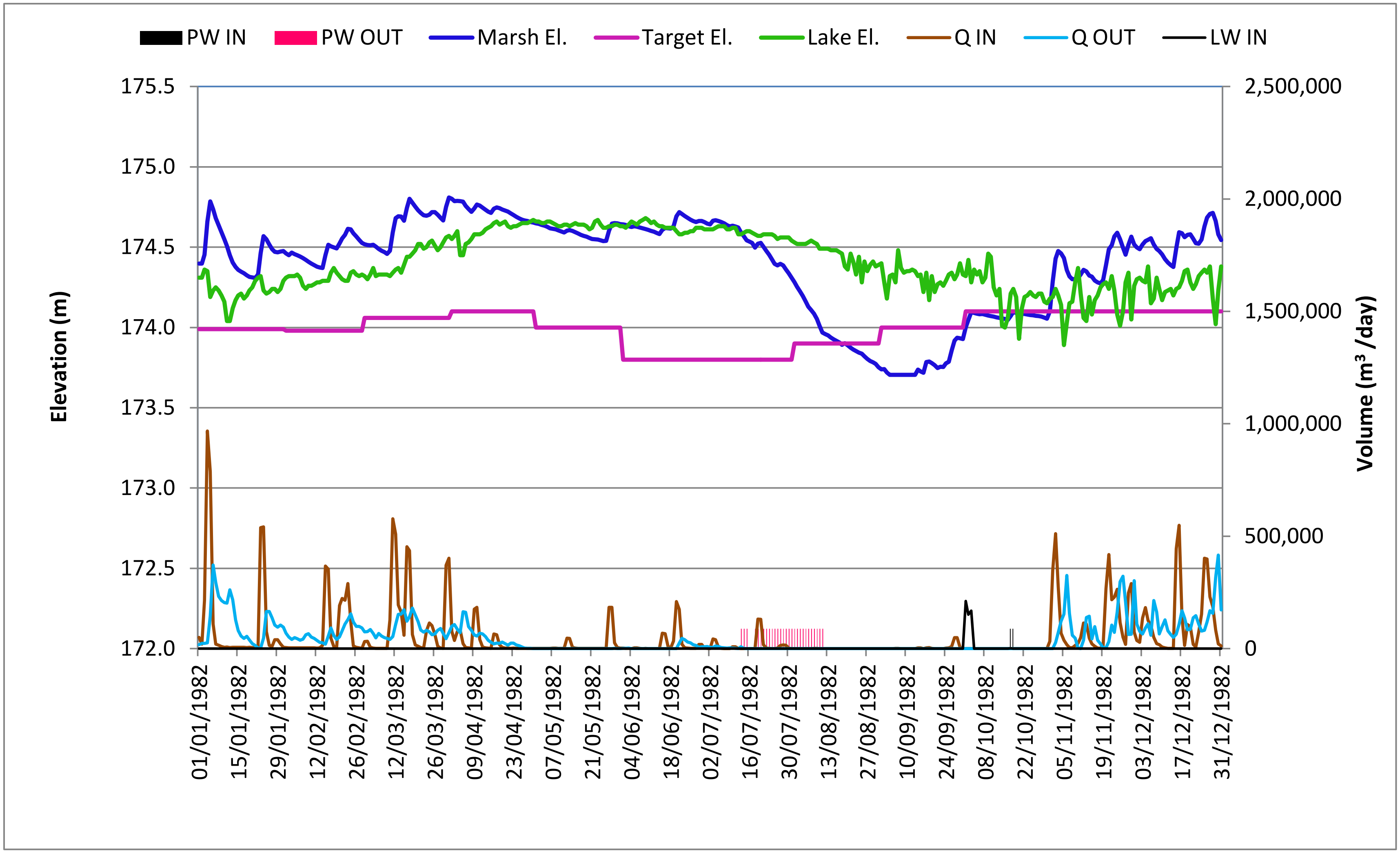


Figure 3: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in a Dry Year, 1982 Condition

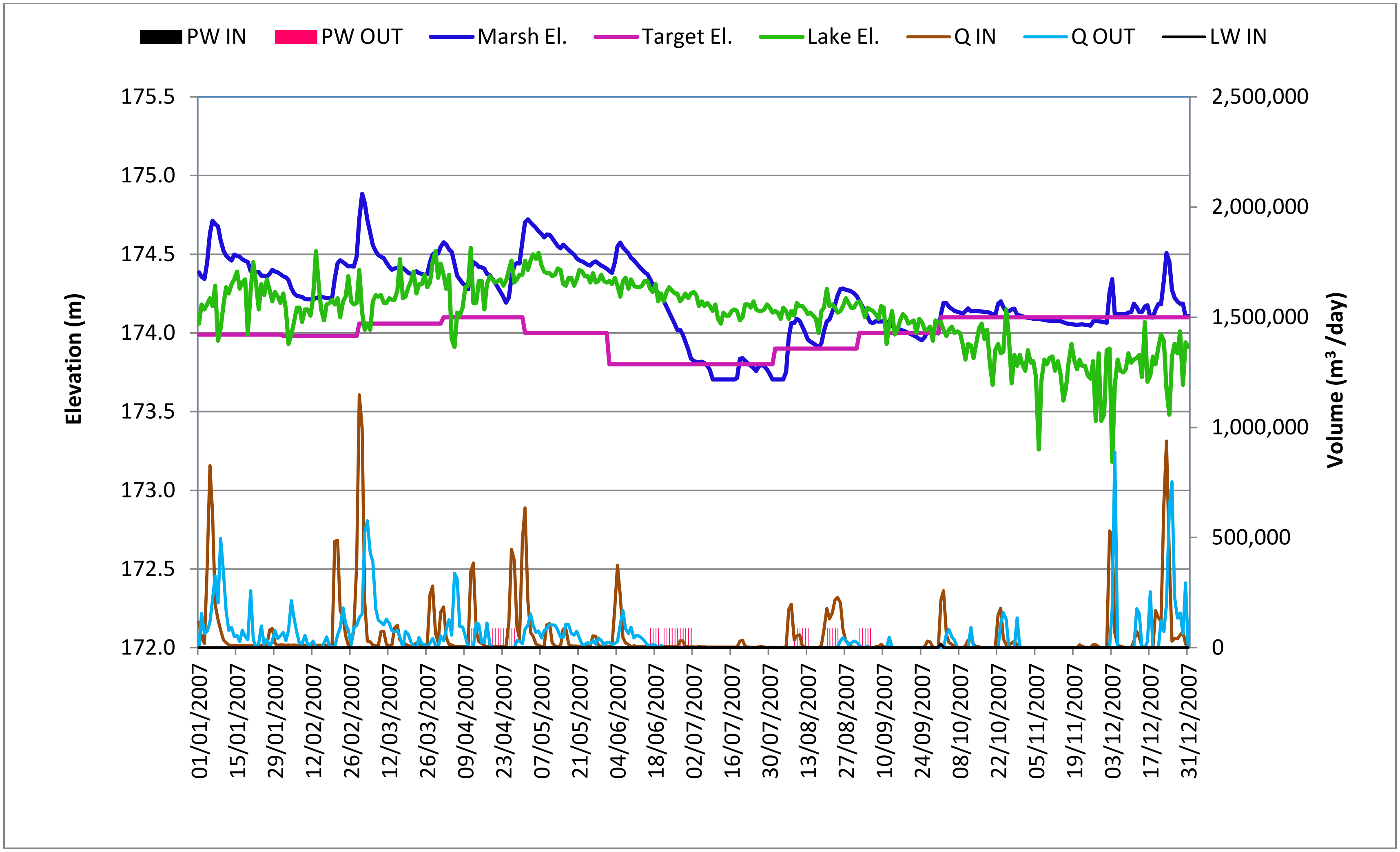


Figure 4: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in an Average Year, 2007 Condition

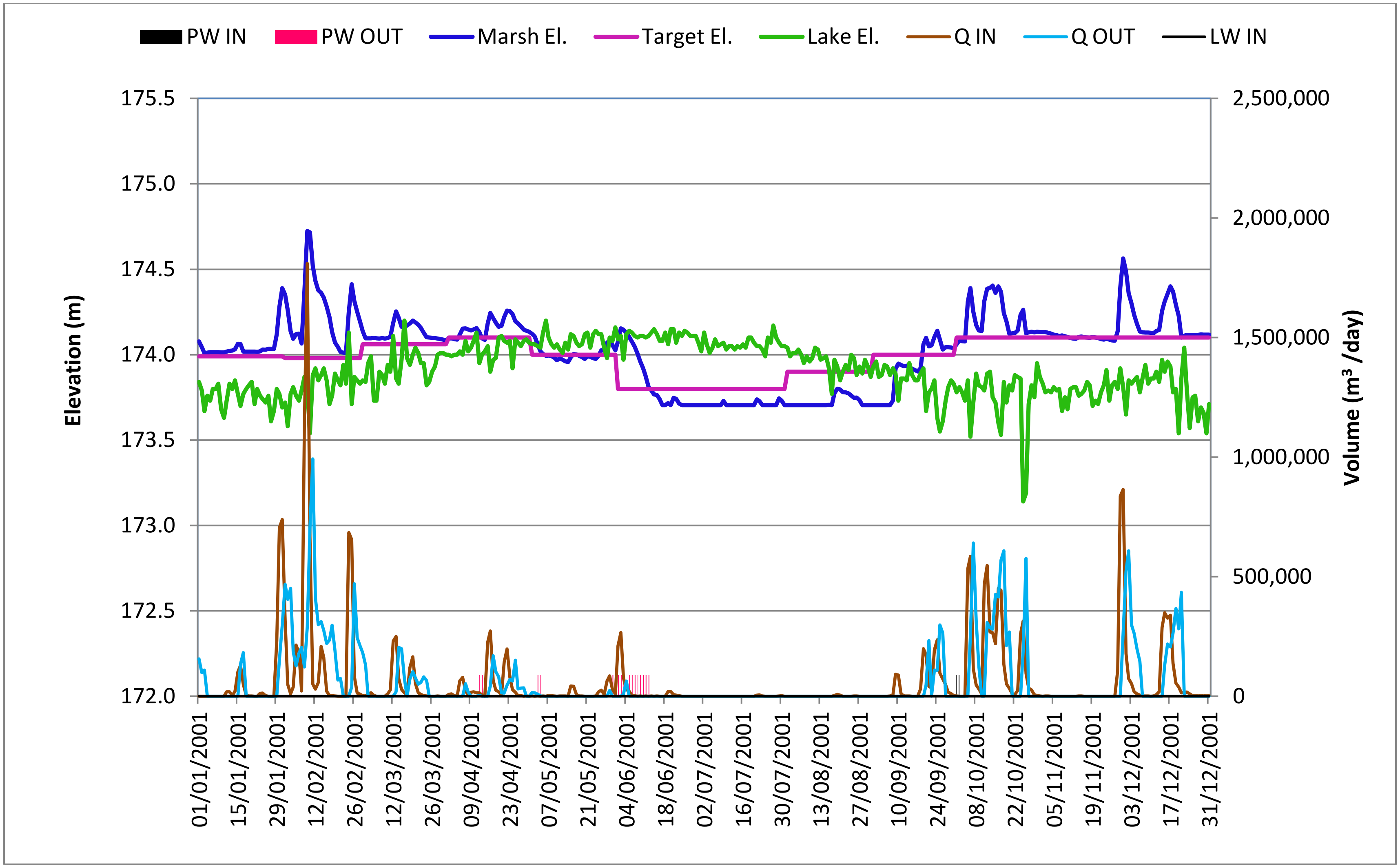


Figure 5: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in an Average Year, 2001 Condition

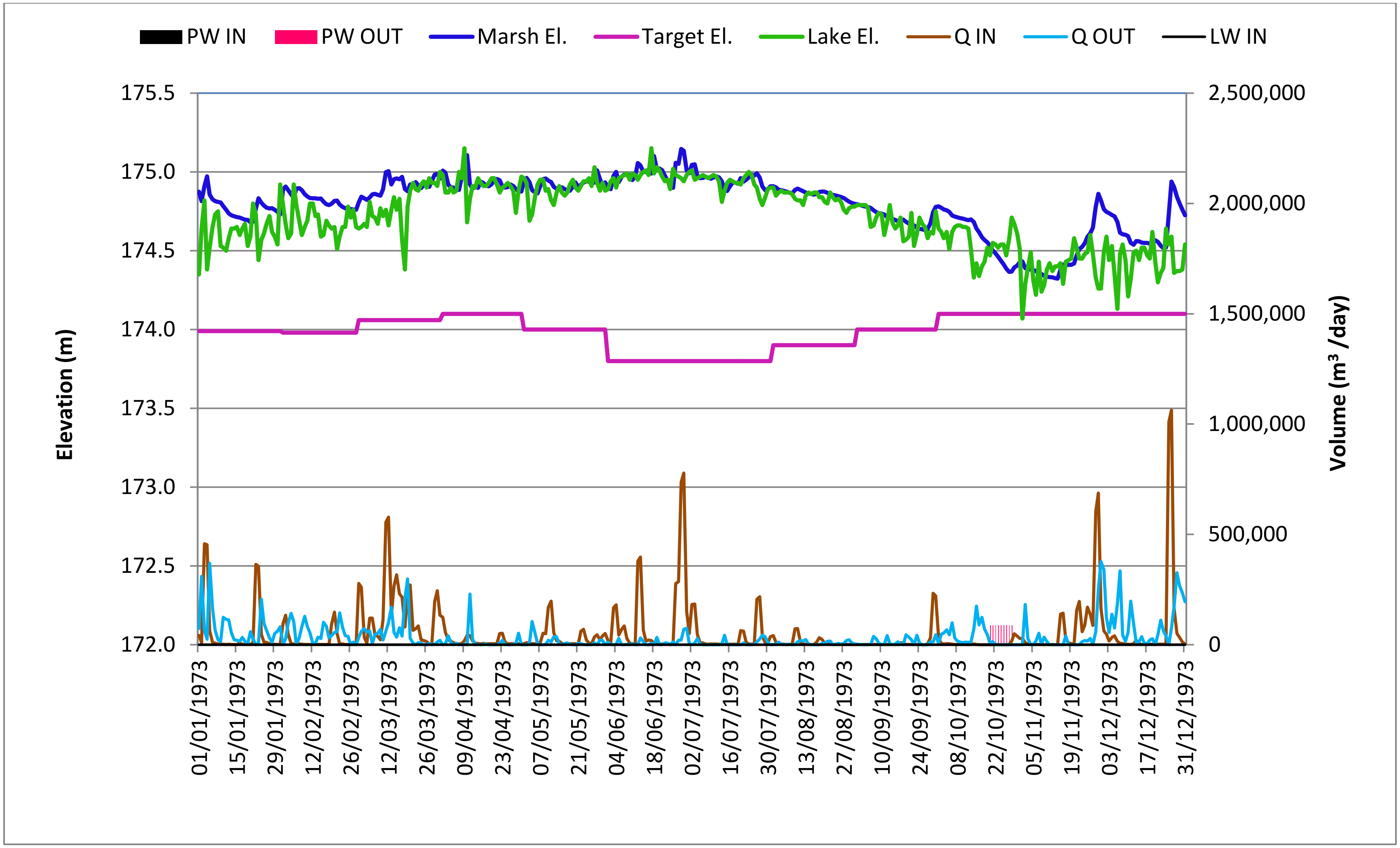


Figure 6: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in an Average Year, 1973 Condition

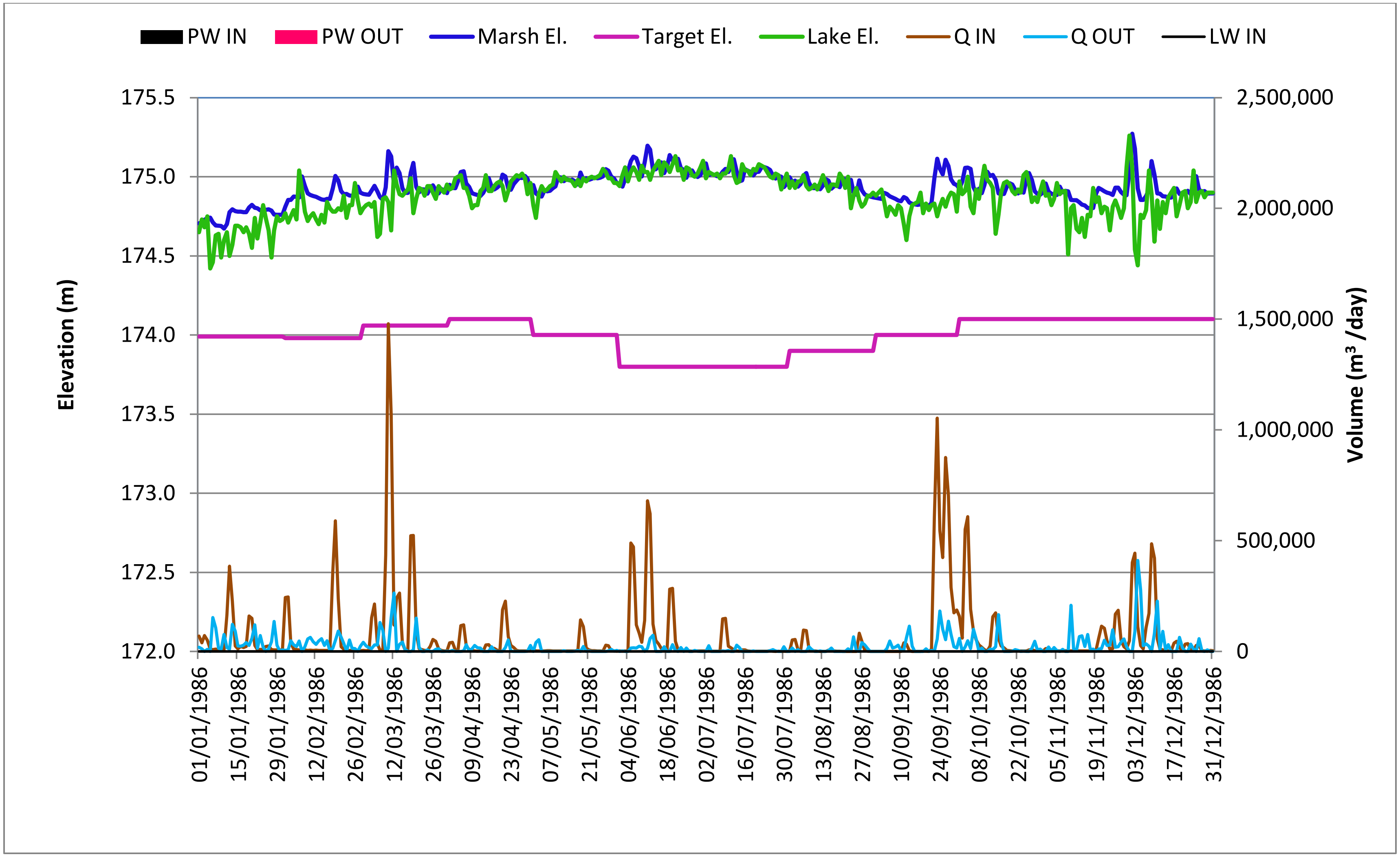


Figure 7: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in a Wet Year, 1986 Condition

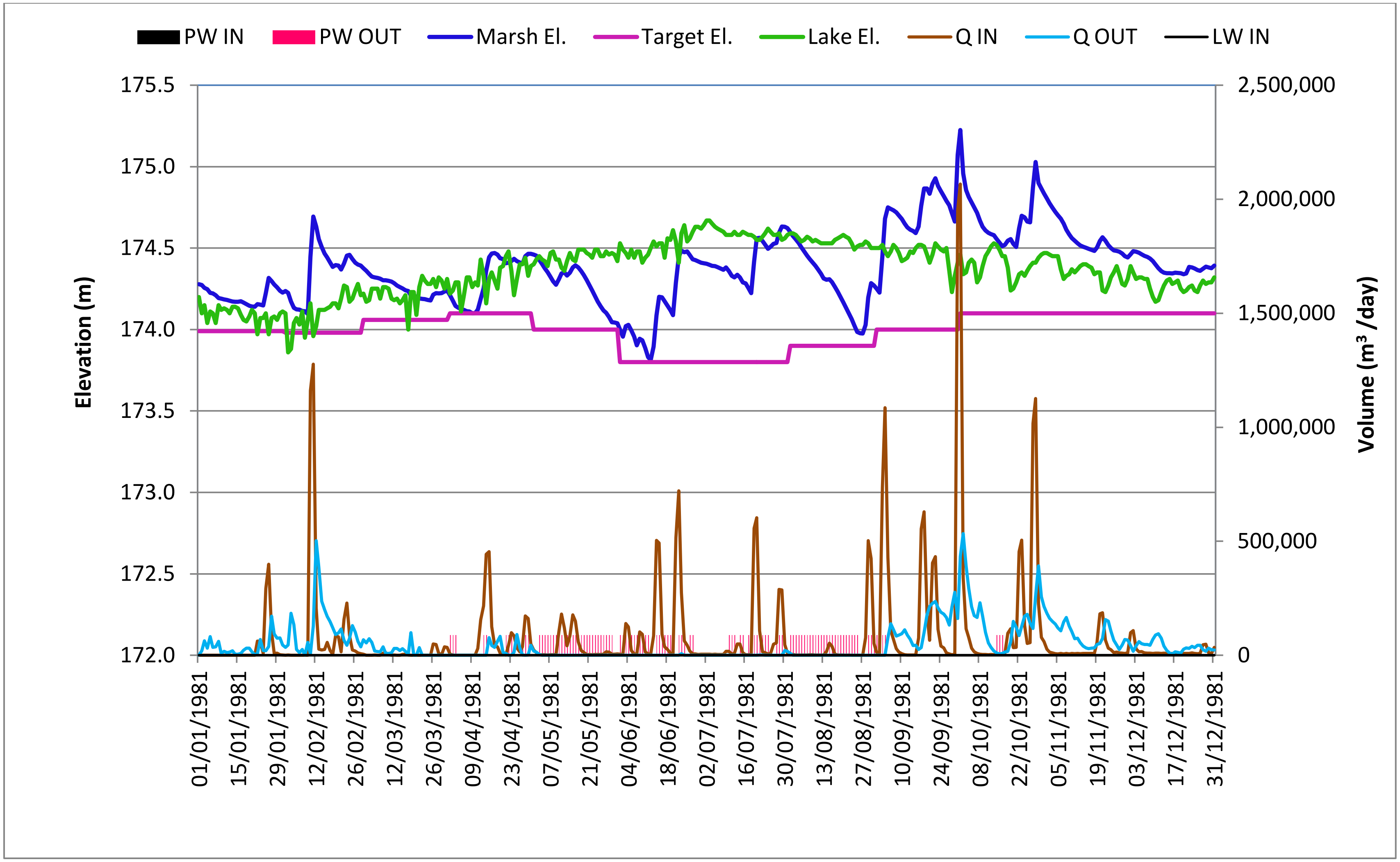


Figure 8: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in a Wet Year, 1981 Condition

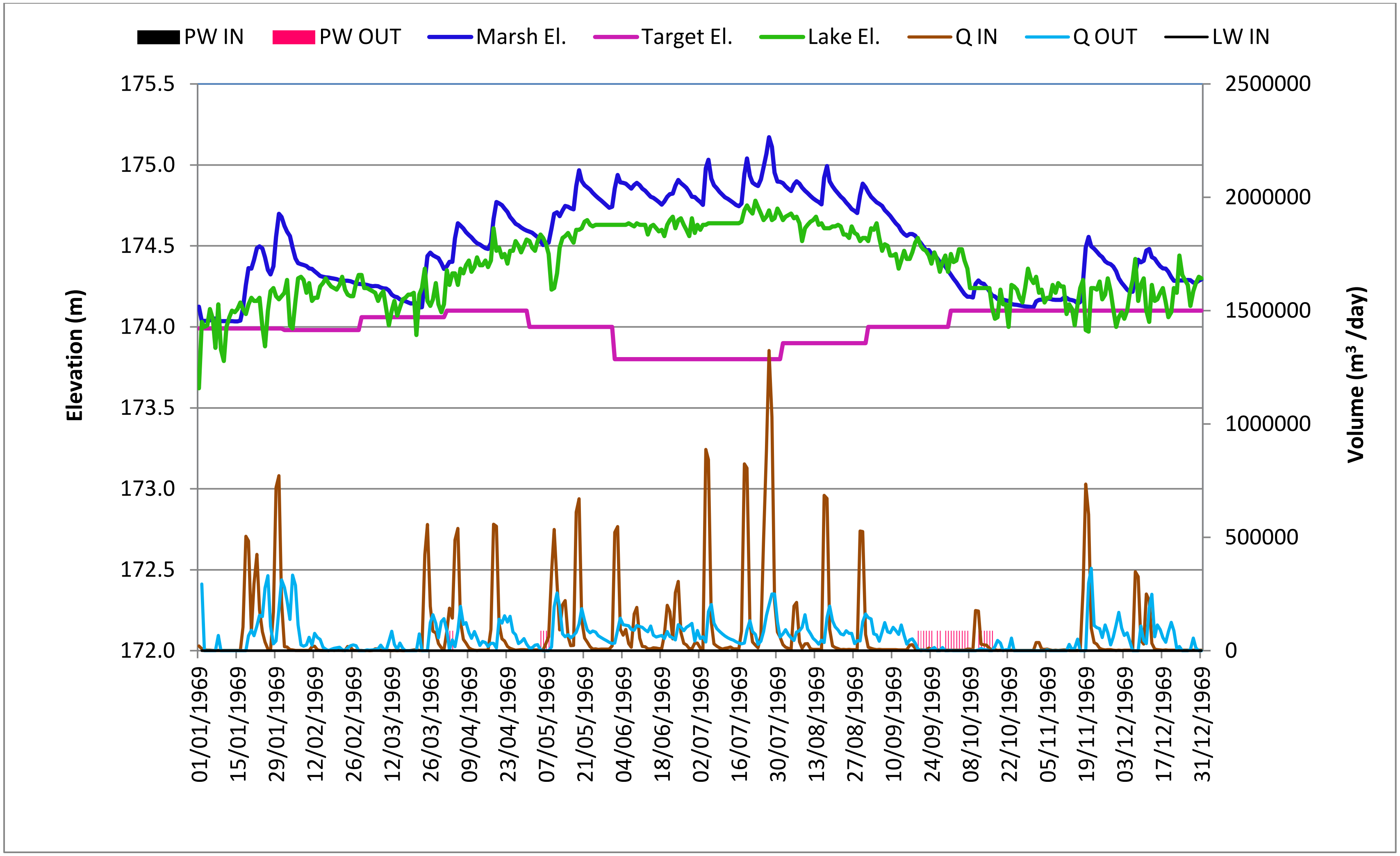


Figure 9: Daily Water Levels, flows and Pumping Water Plot for Open Water Marsh in a Wet Year, 1969 Condition

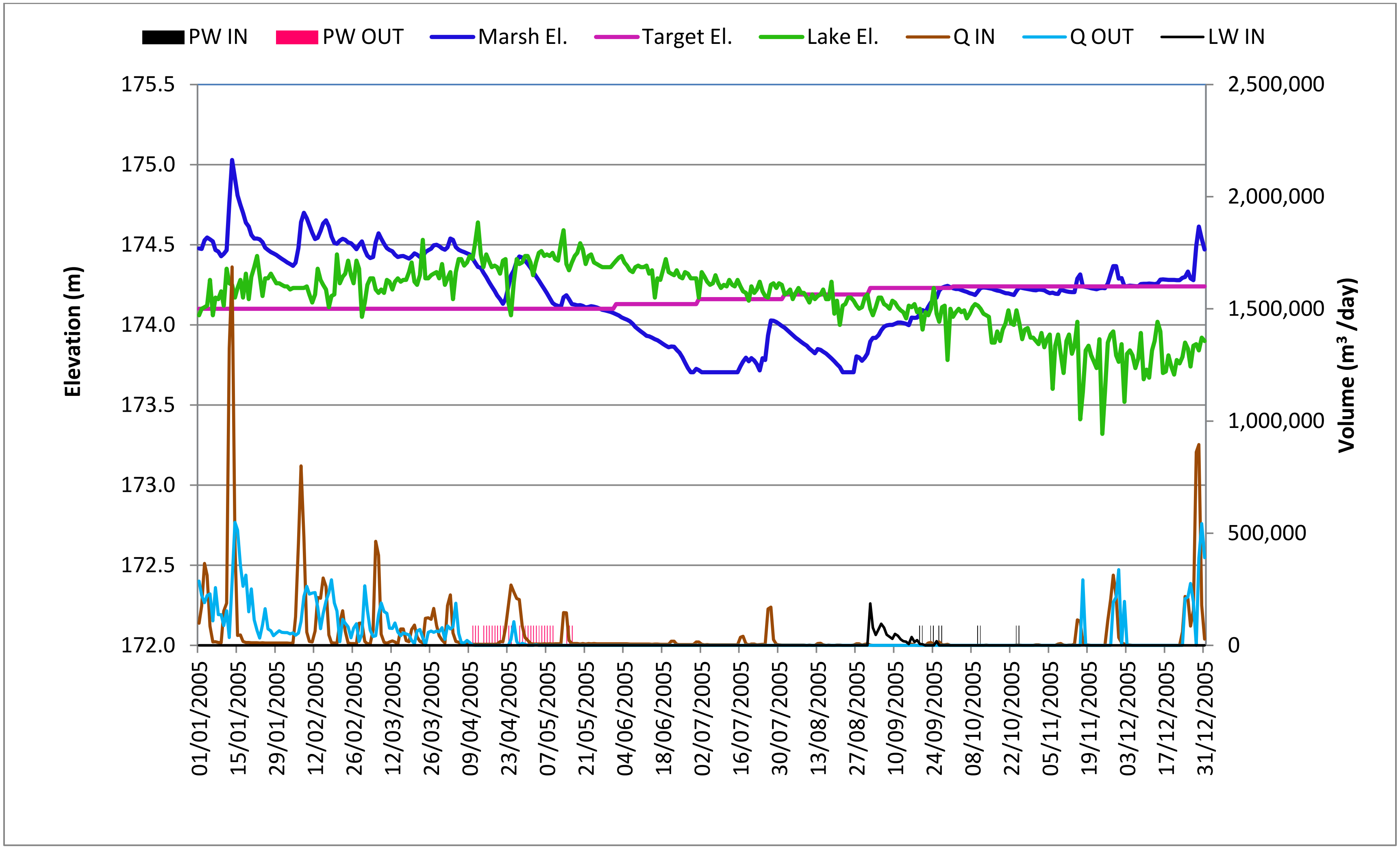


Figure 10: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in a Dry Year, 2005 Condition

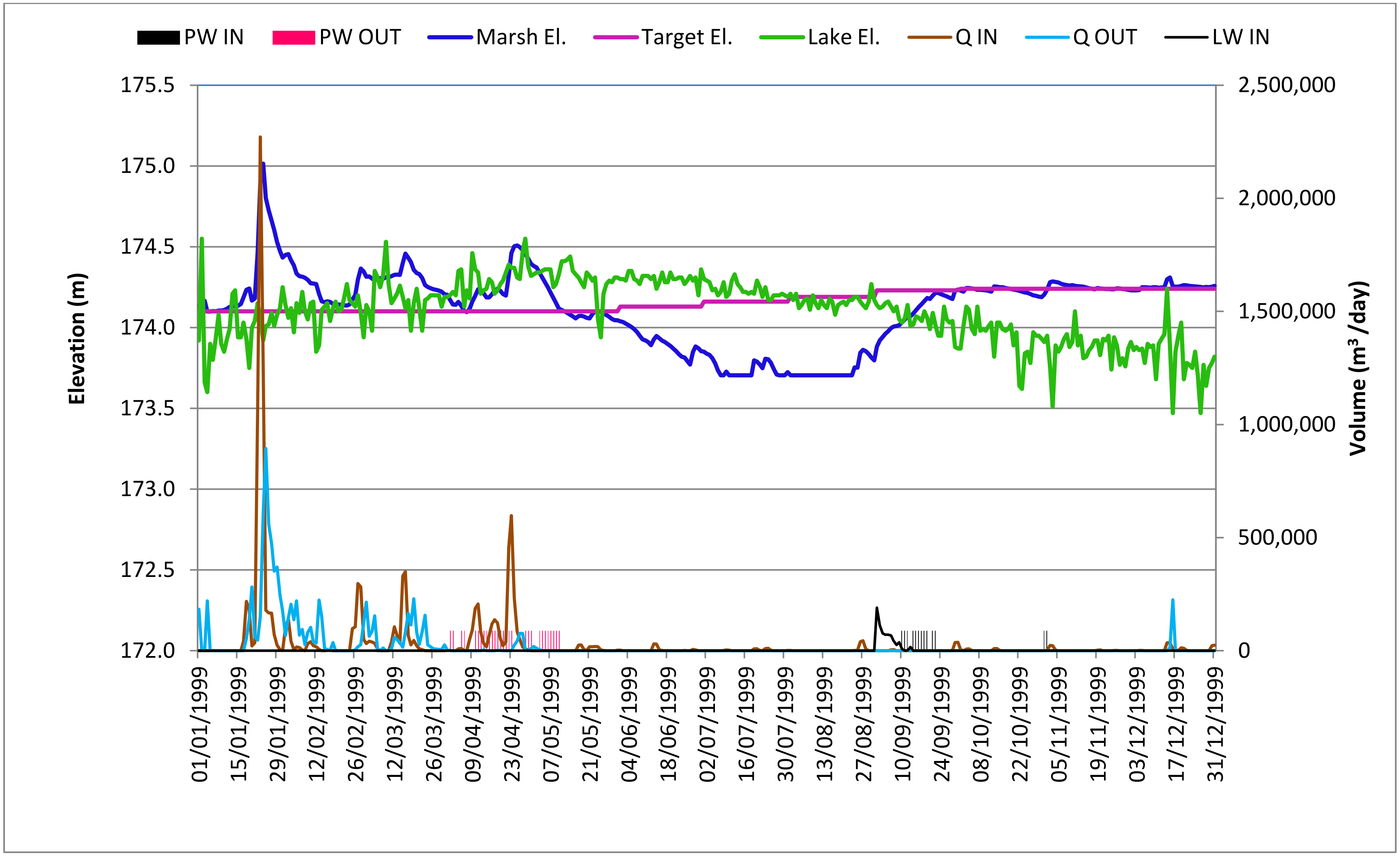


Figure 11: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in a Dry Year, 1999 Condition

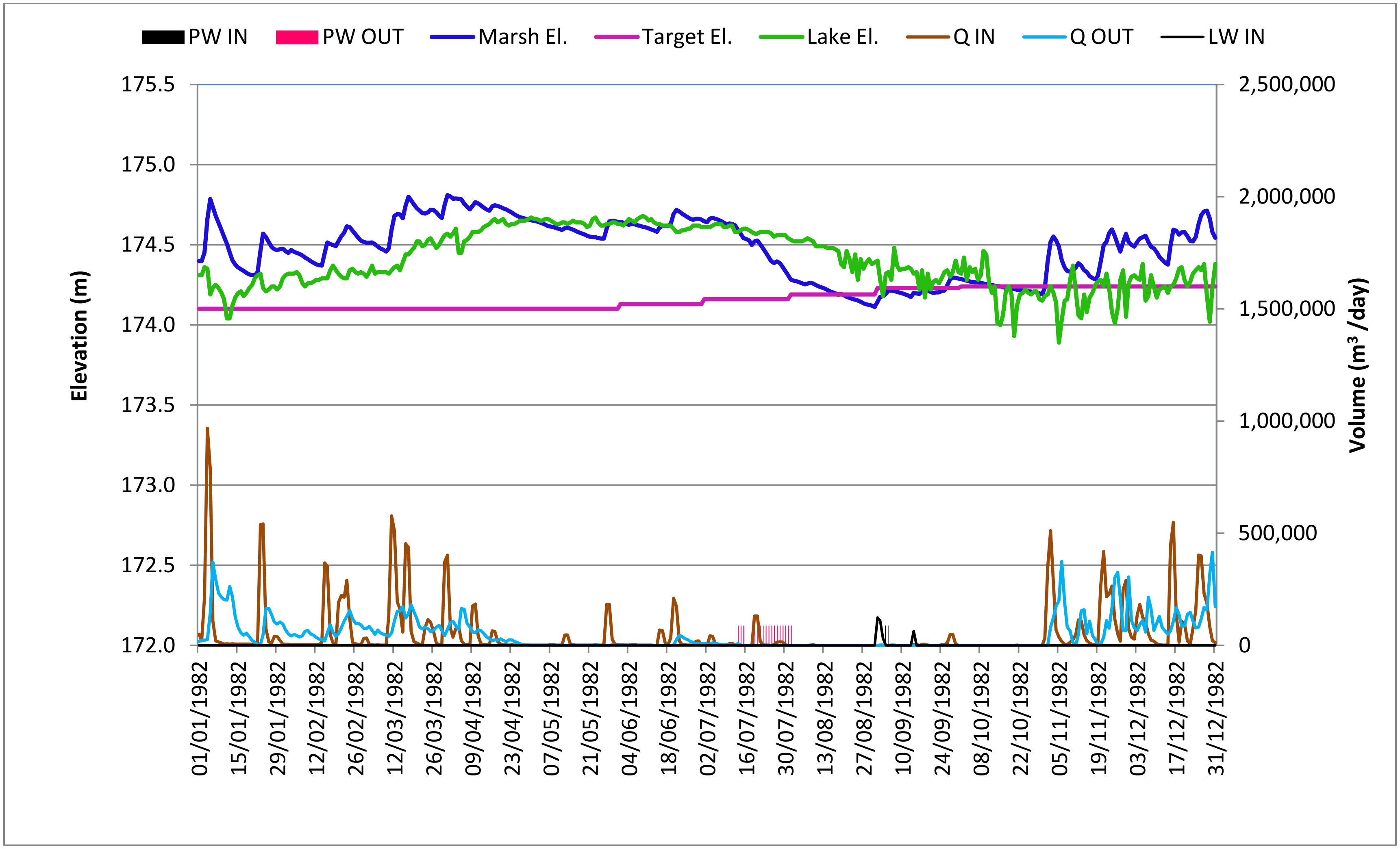


Figure 12: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in a Dry Year, 1982 Condition

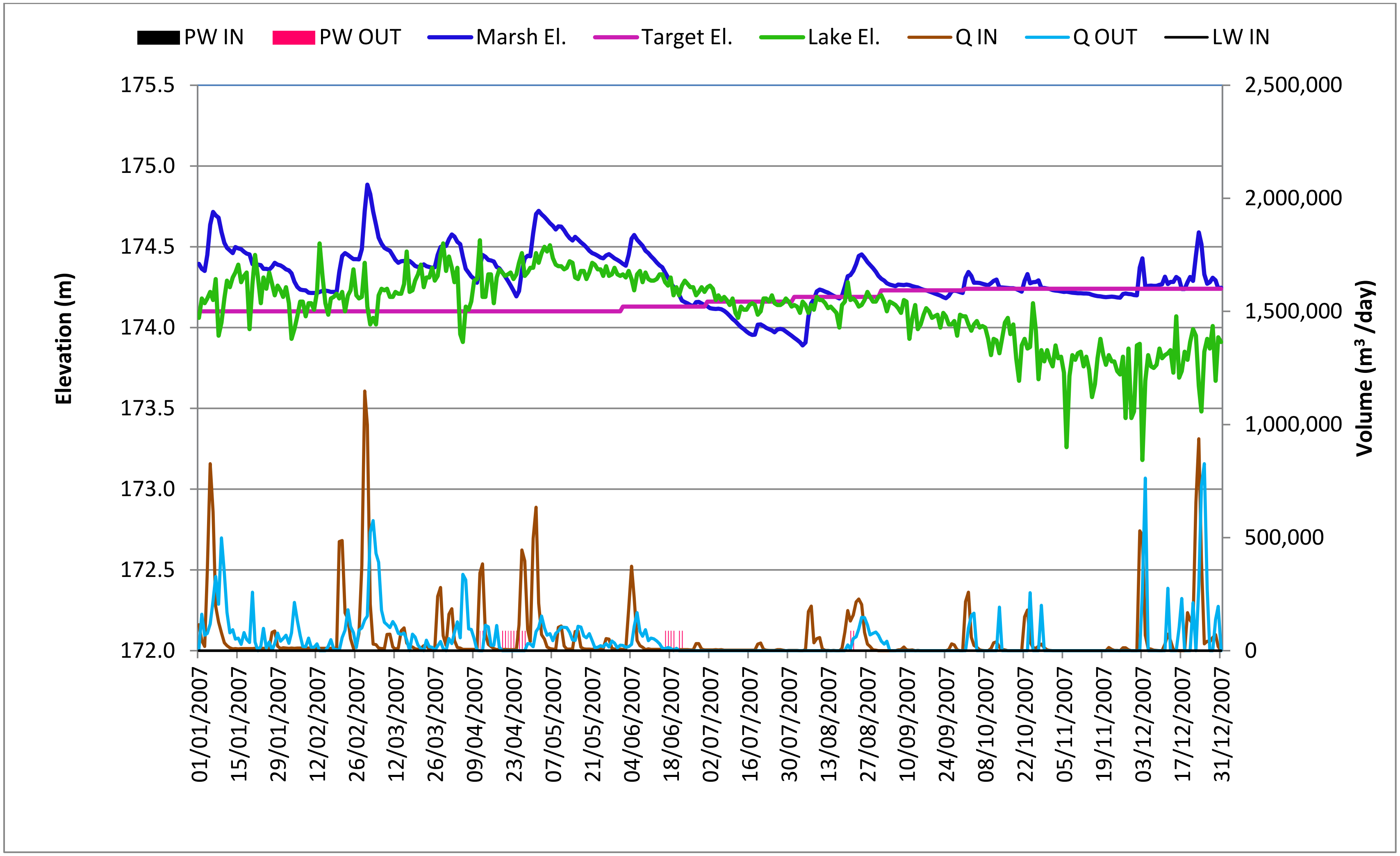


Figure 13: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in an Average Year, 2007 Condition

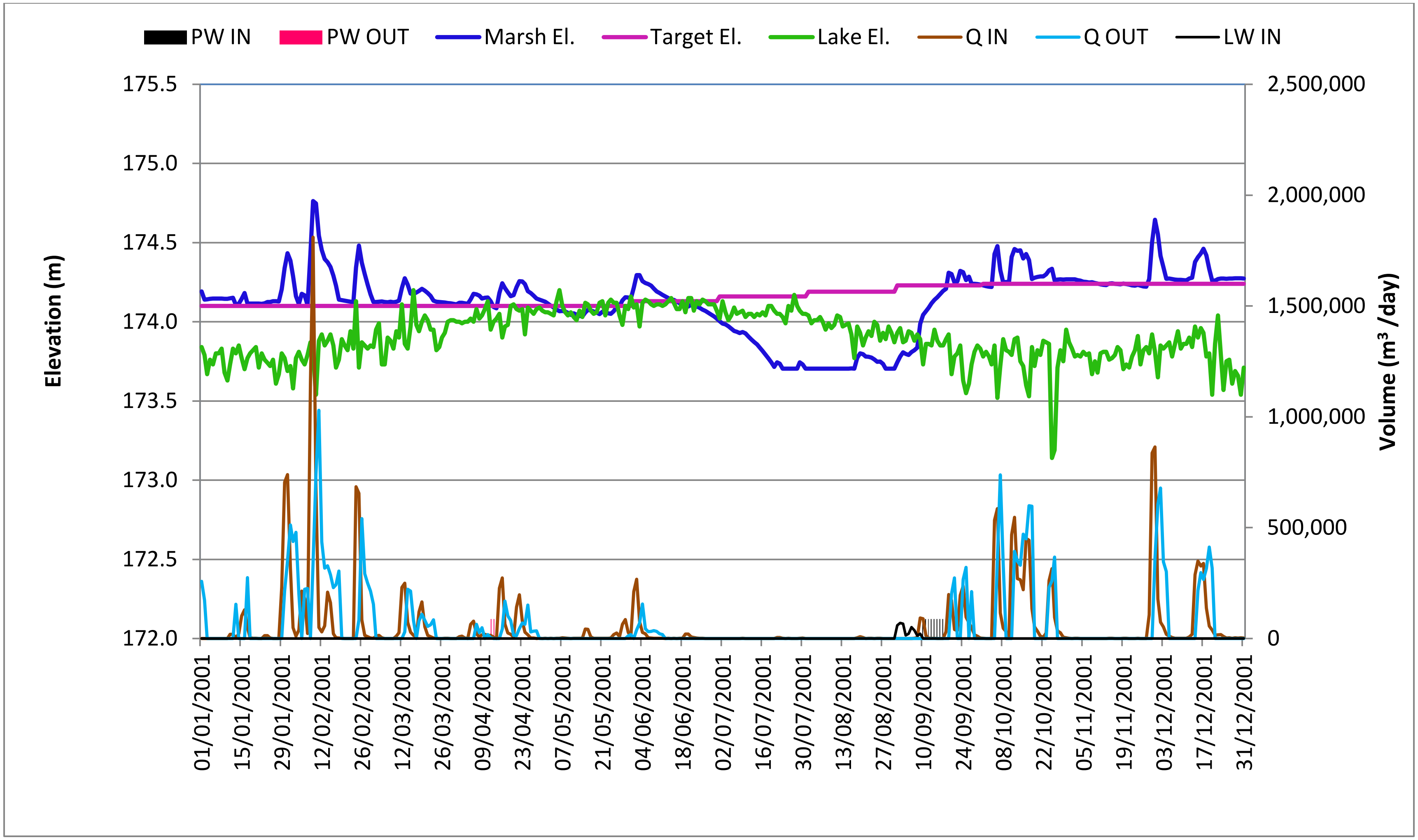


Figure 14: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in an Average Year, 2001 Condition

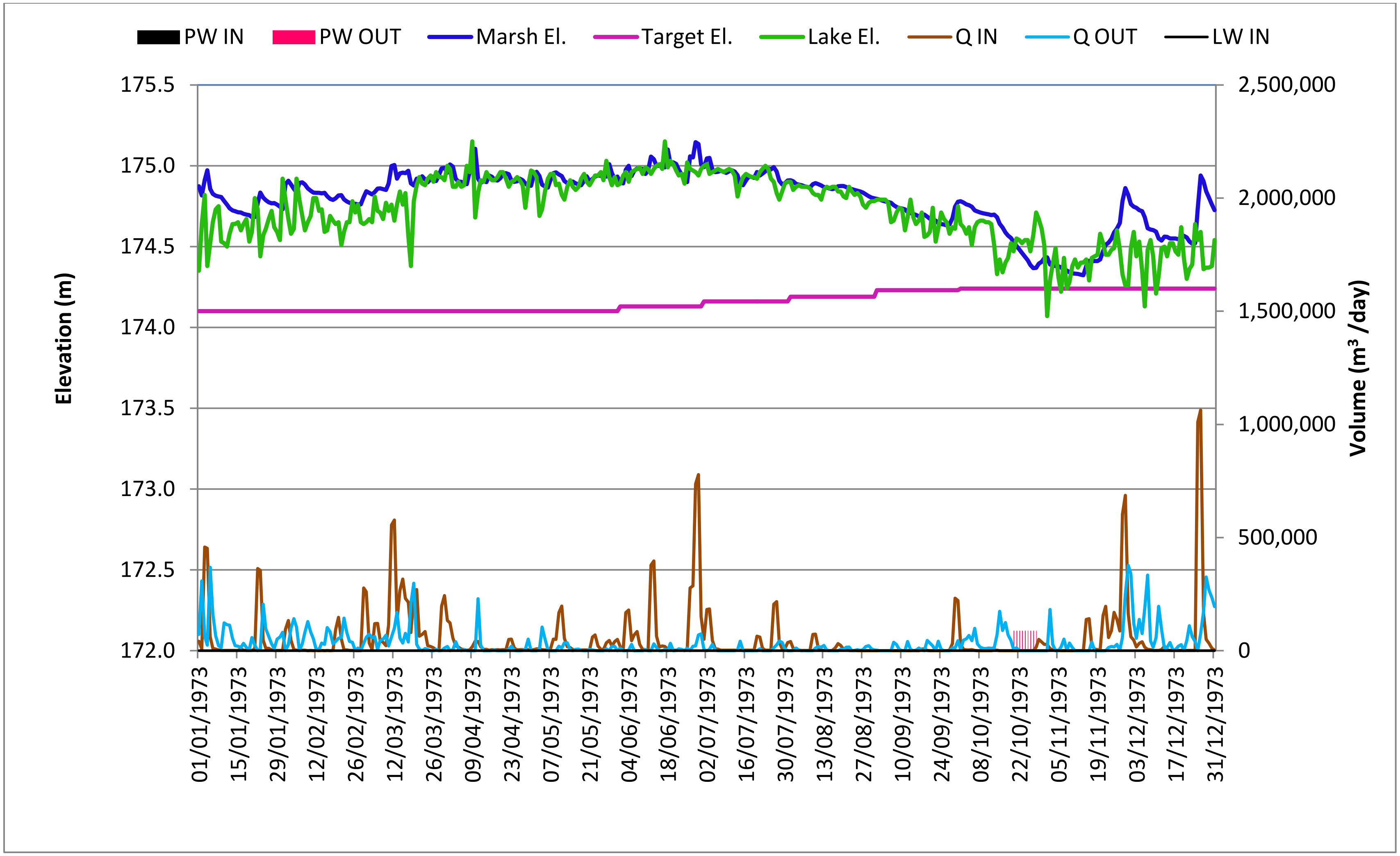


Figure 15: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in an Average Year, 1973 Condition

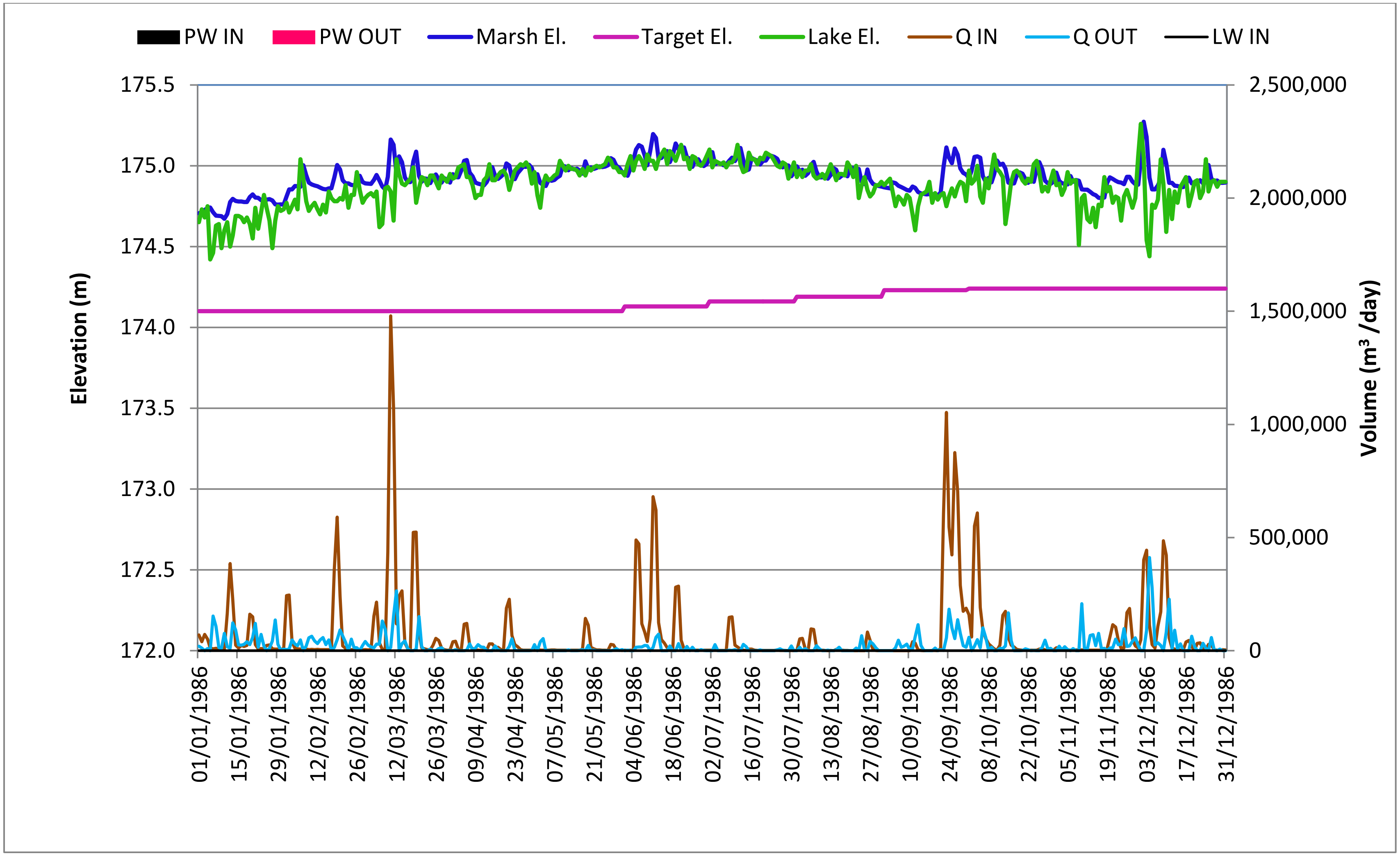


Figure 16: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in a Wet Year, 1986 Condition

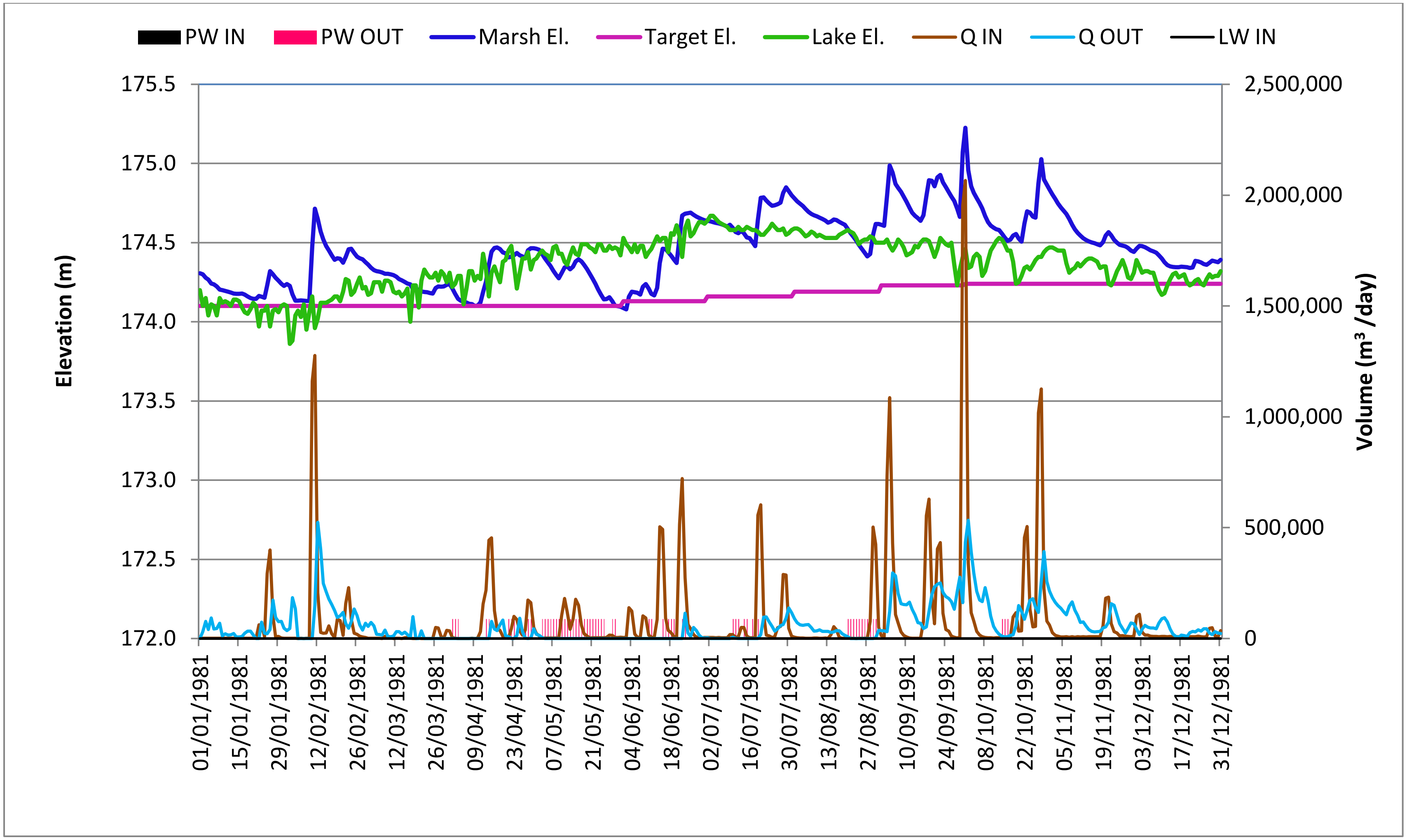


Figure 17: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in a Wet Year, 1981 Condition

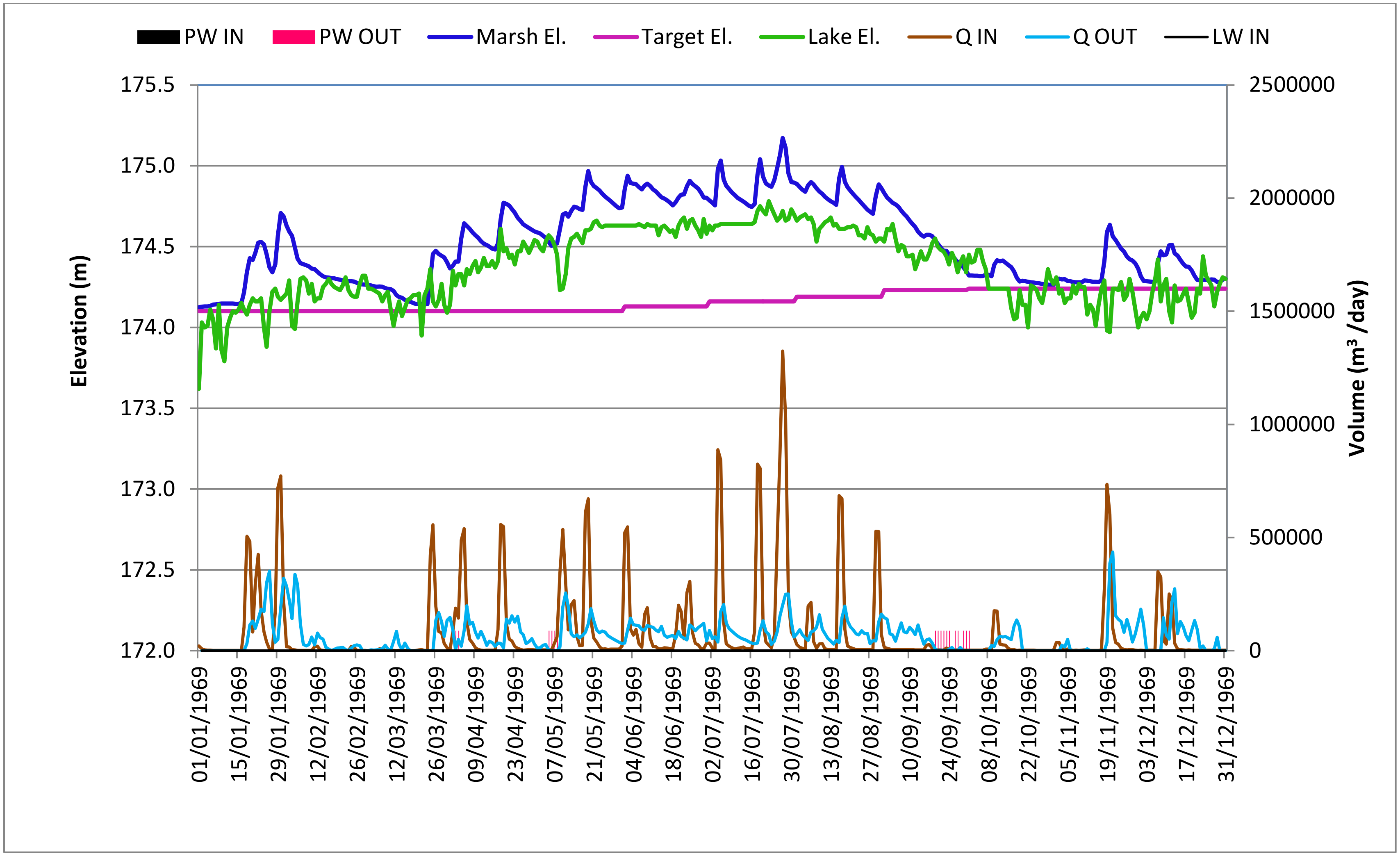


Figure 18: Daily Water Levels, flows and Pumping Water Plot for Open Water 2 Marsh in a Wet Year, 1969 Condition

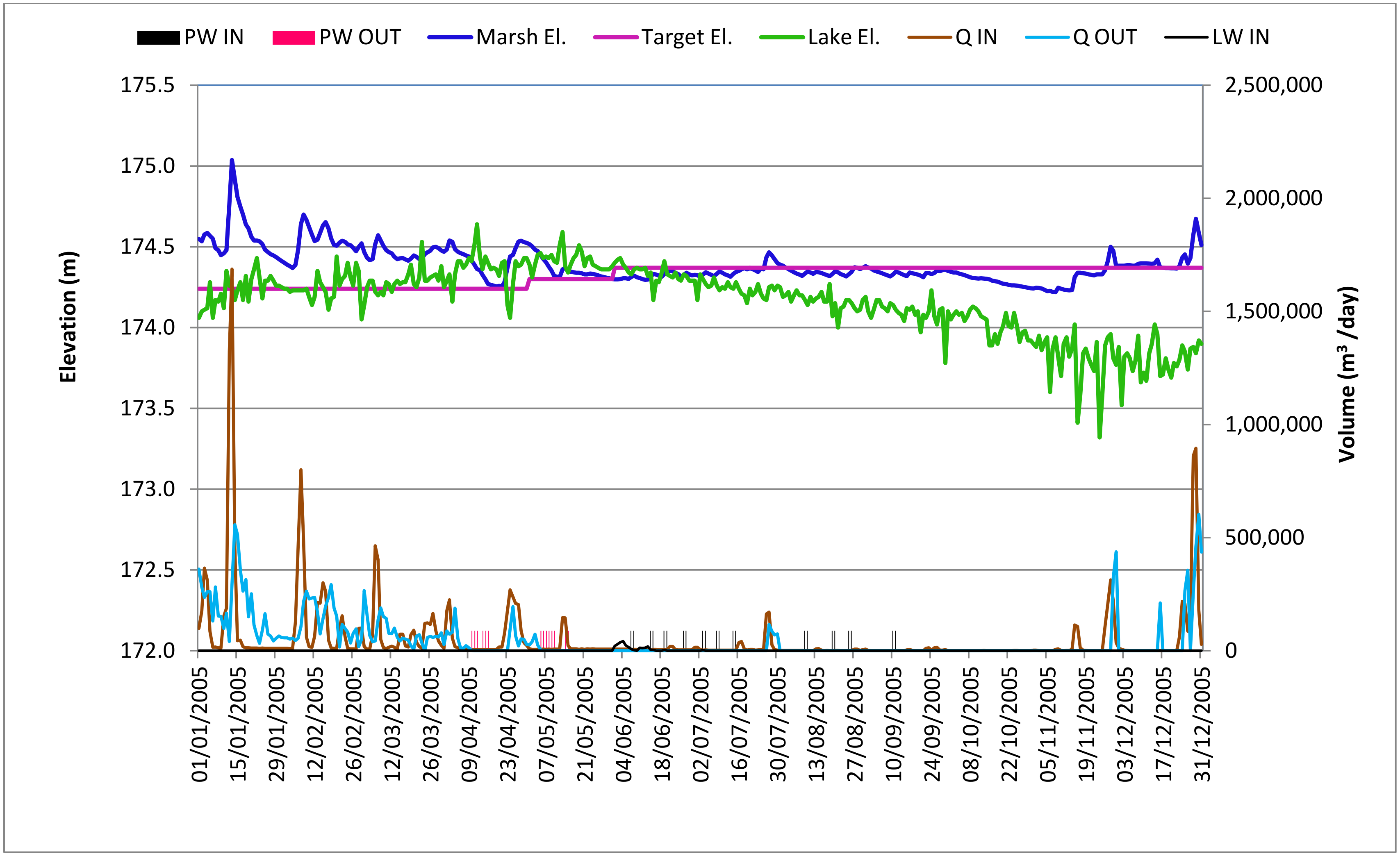


Figure 19: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in a dry Year, 2005 Condition

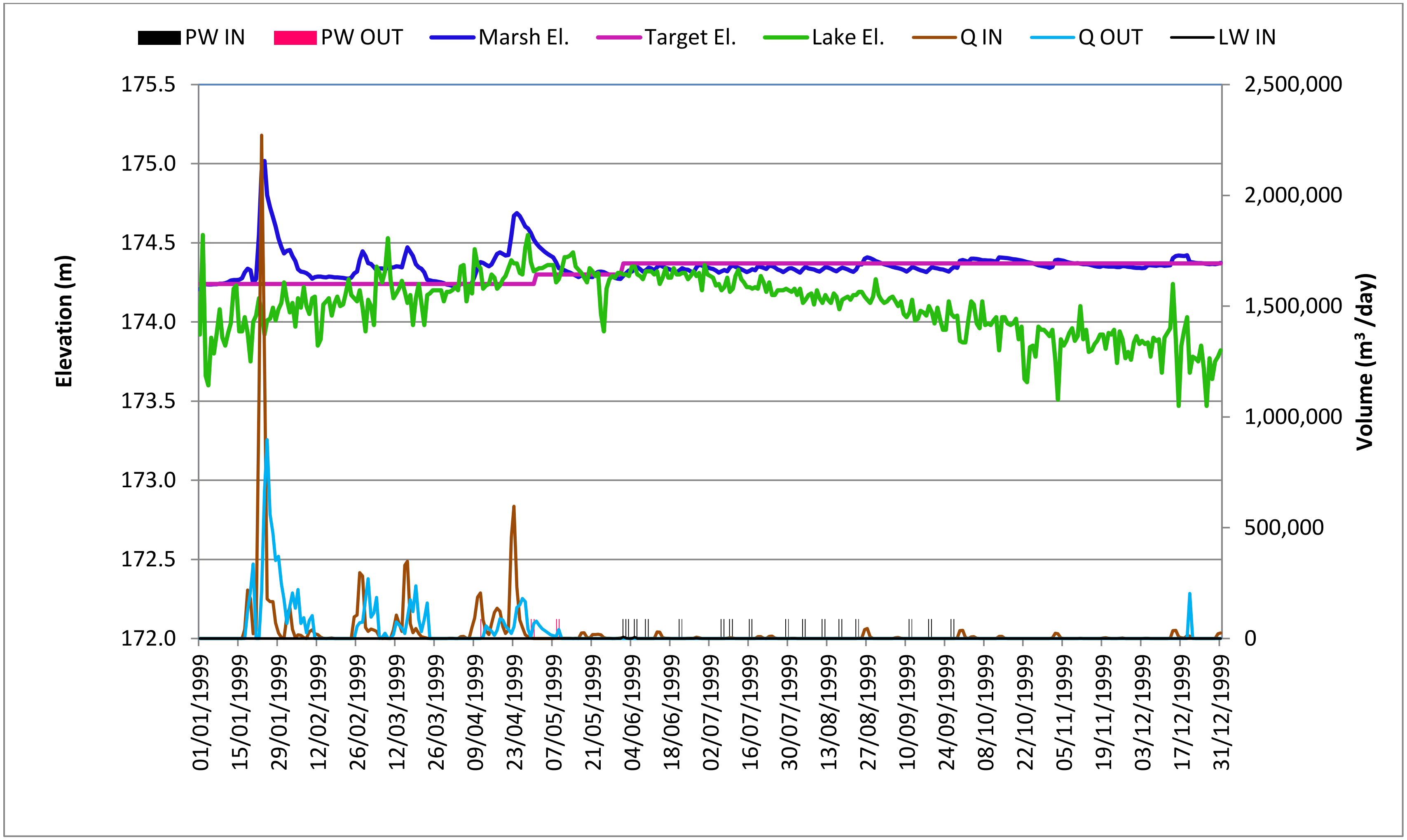


Figure 20: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in a dry Year, 1999 Condition

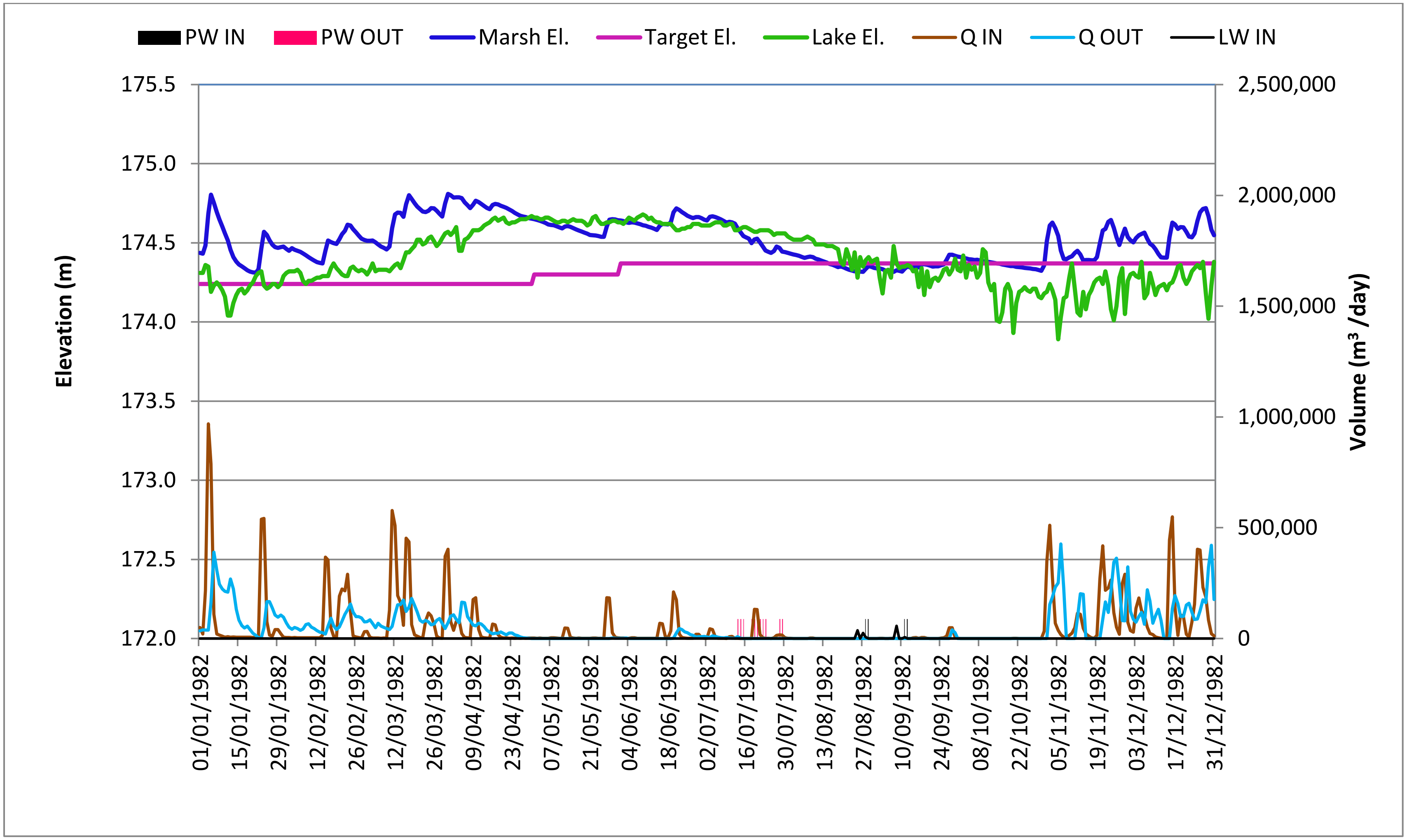


Figure 21: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in a dry Year, 1982 Condition

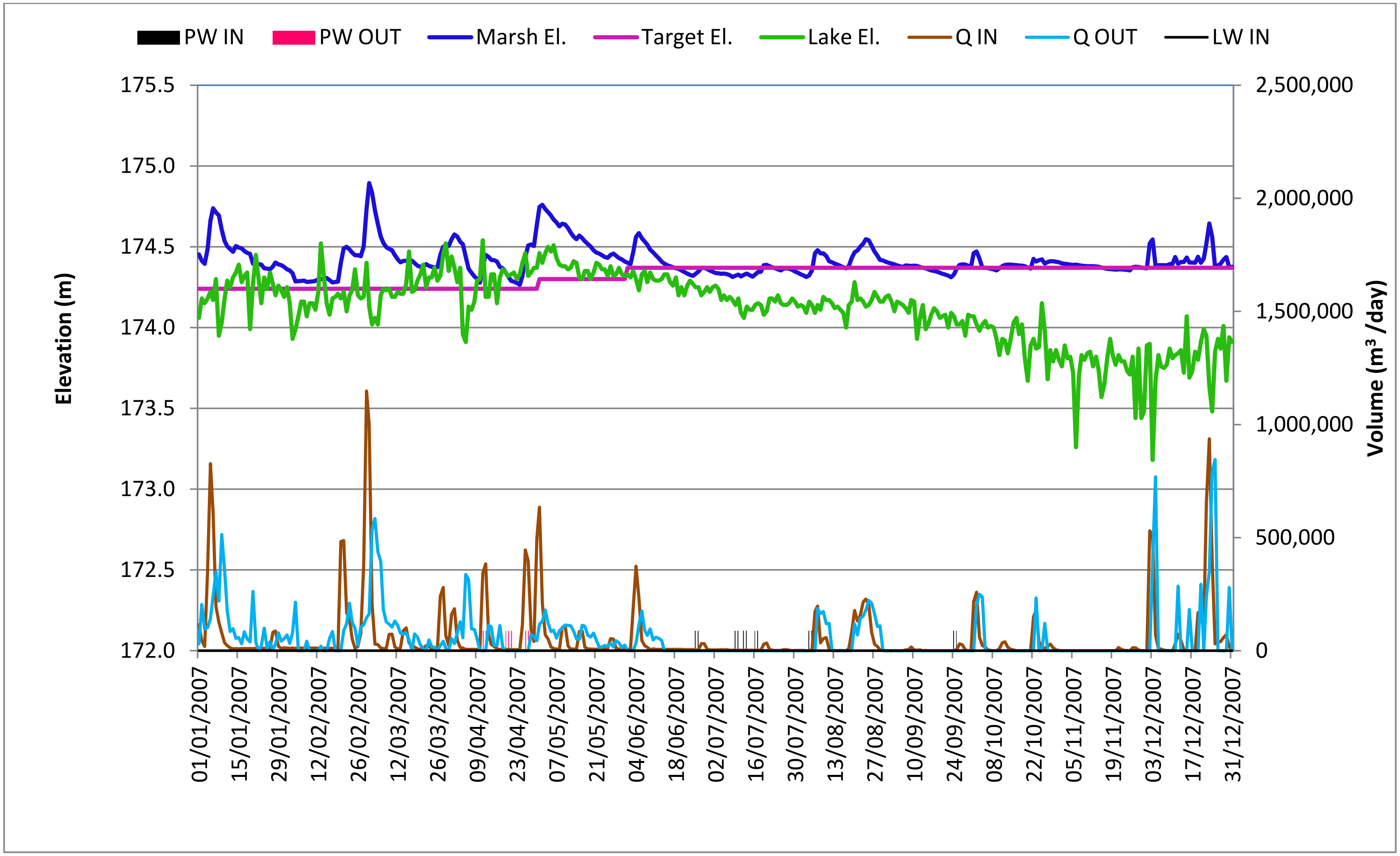


Figure 22: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in an Average Year, 2007 Condition

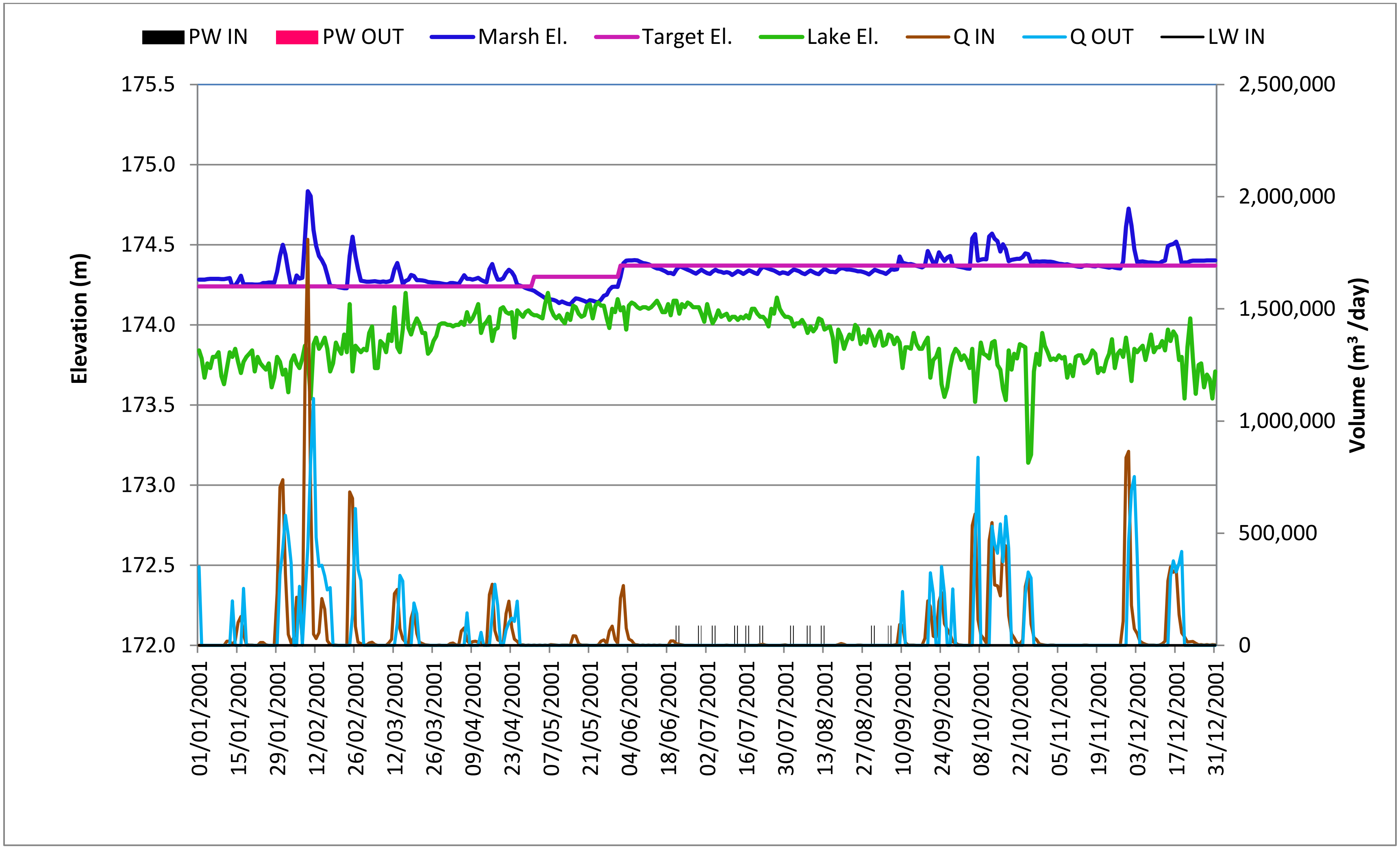


Figure 23: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in an Average Year, 2001 Condition

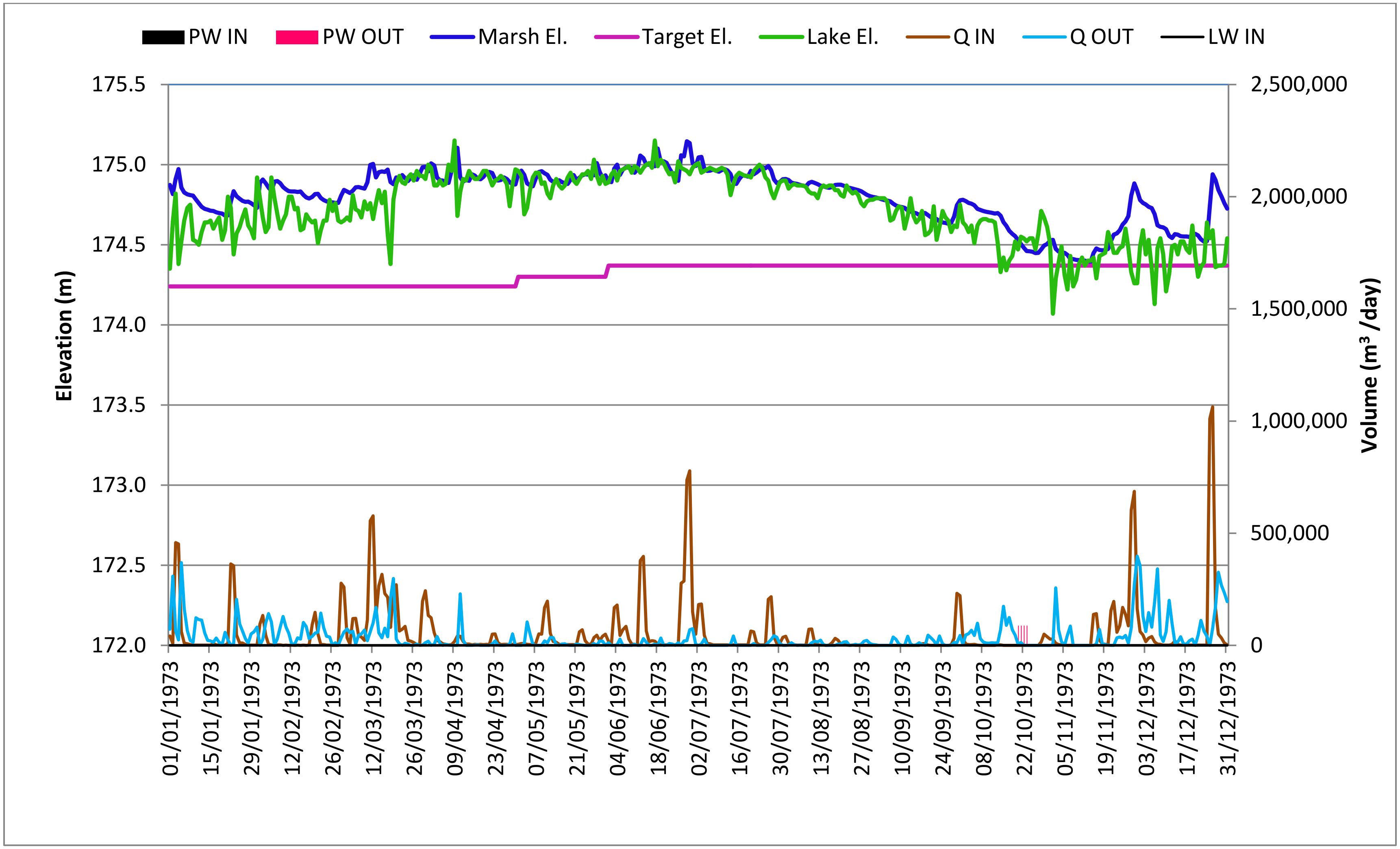


Figure 24: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in an Average Year, 1973 Condition

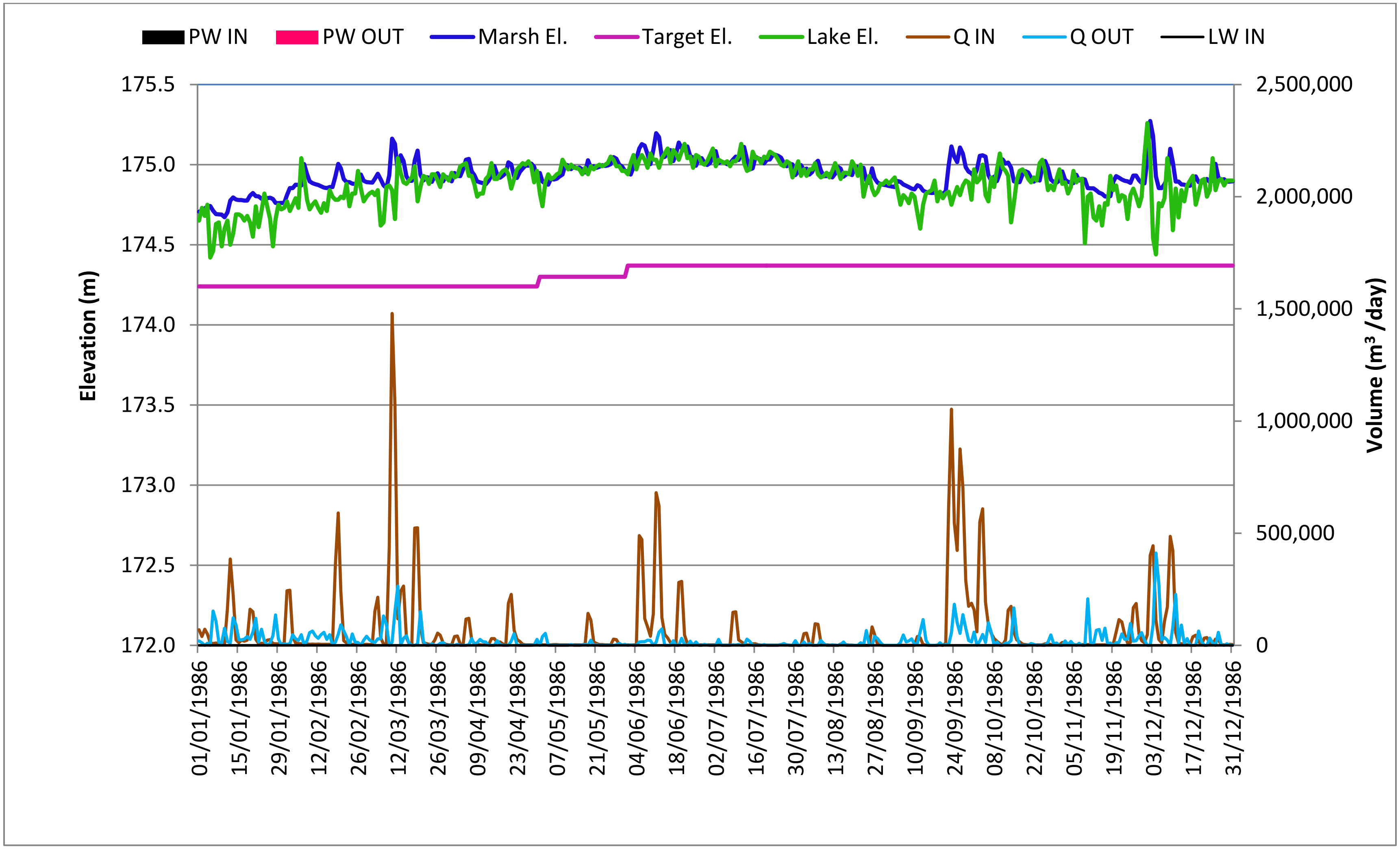


Figure 25: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in a Wet Year, 1986 Condition

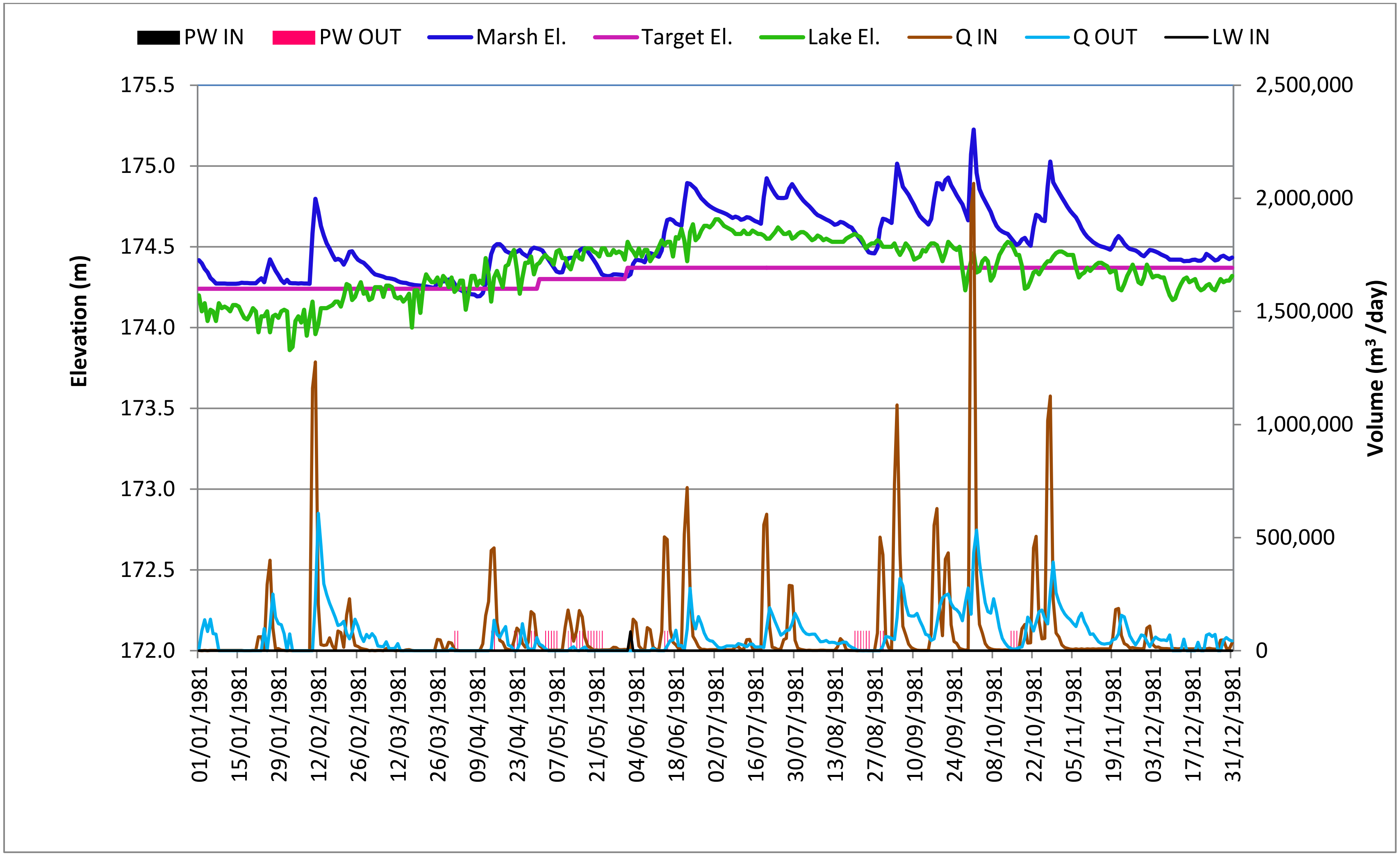


Figure 26: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in a Wet Year, 1981 Condition

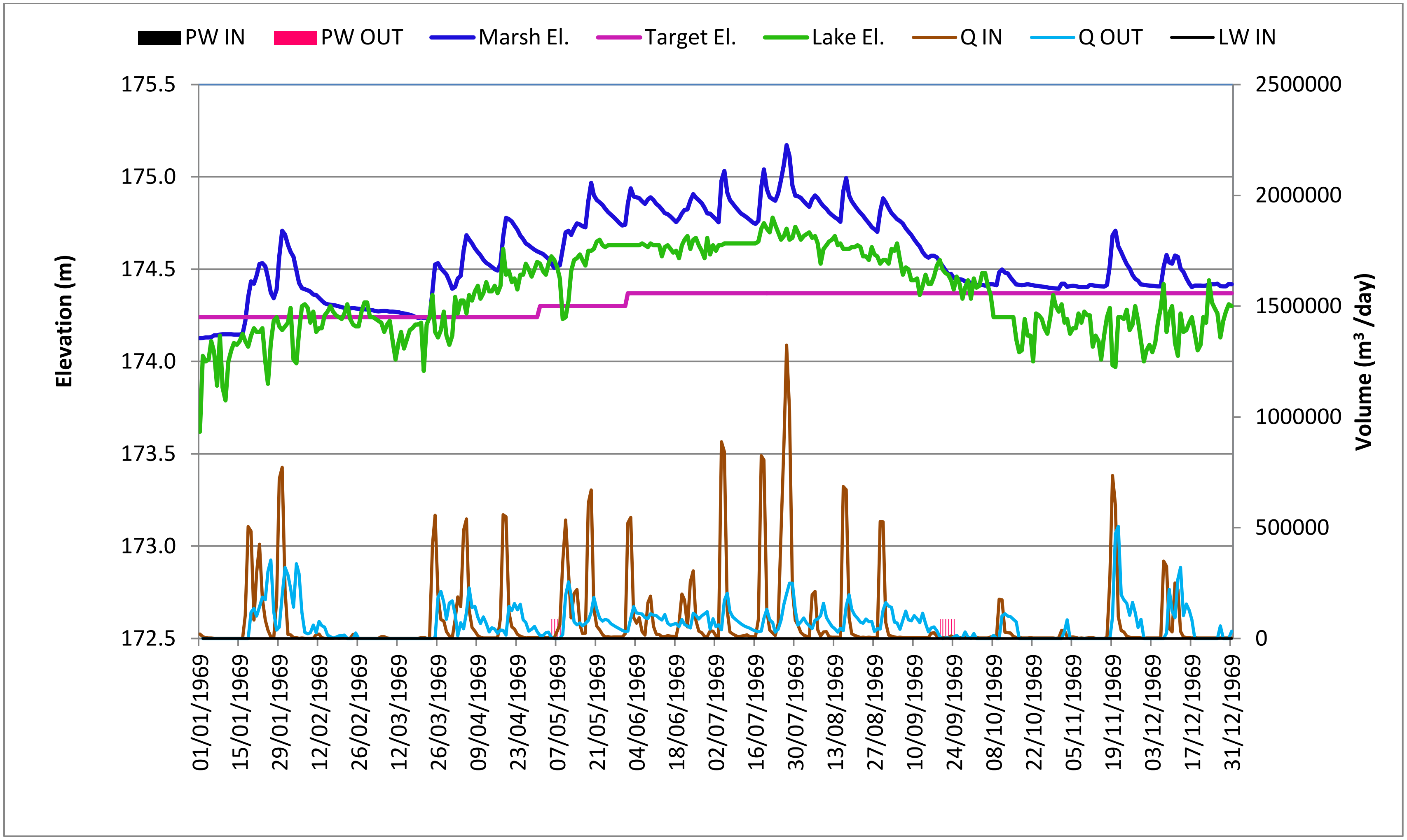


Figure 27: Daily Water Levels, flows and Pumping Water Plot for Hemi Marsh in a Wet Year, 1981 Condition

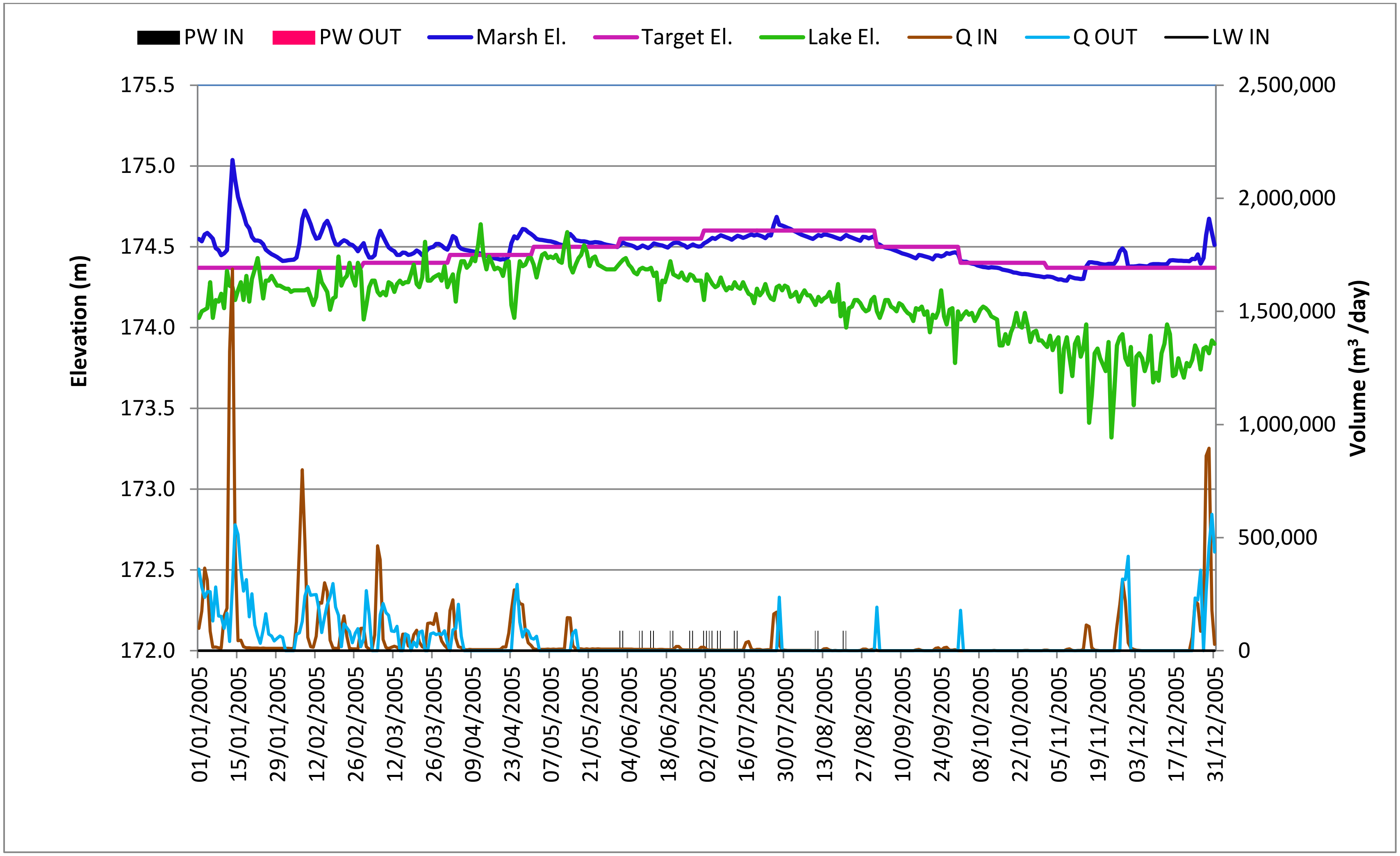


Figure 28: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in a Dry Year, 2005 Condition

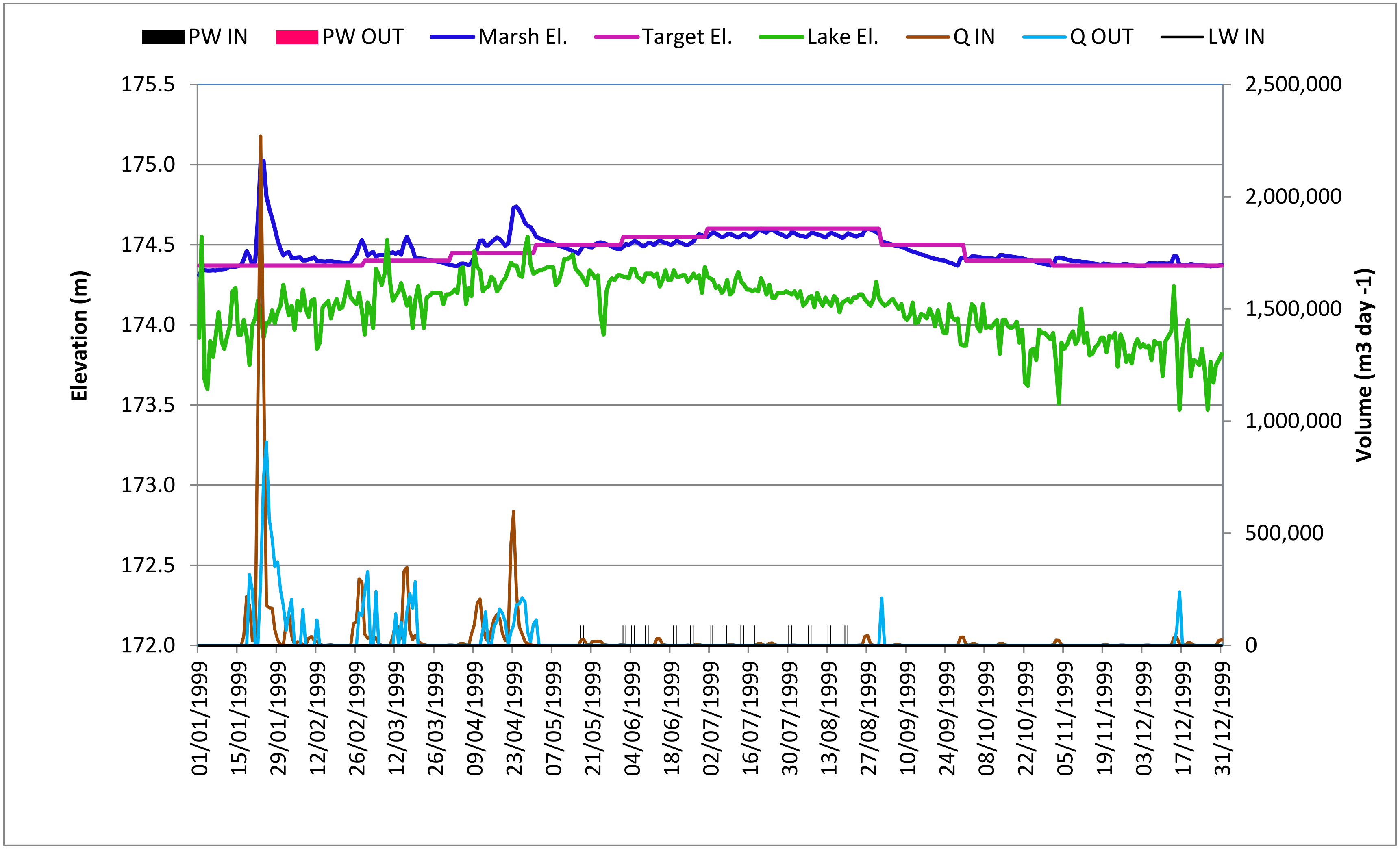


Figure 29: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in a Dry Year, 1999 Condition

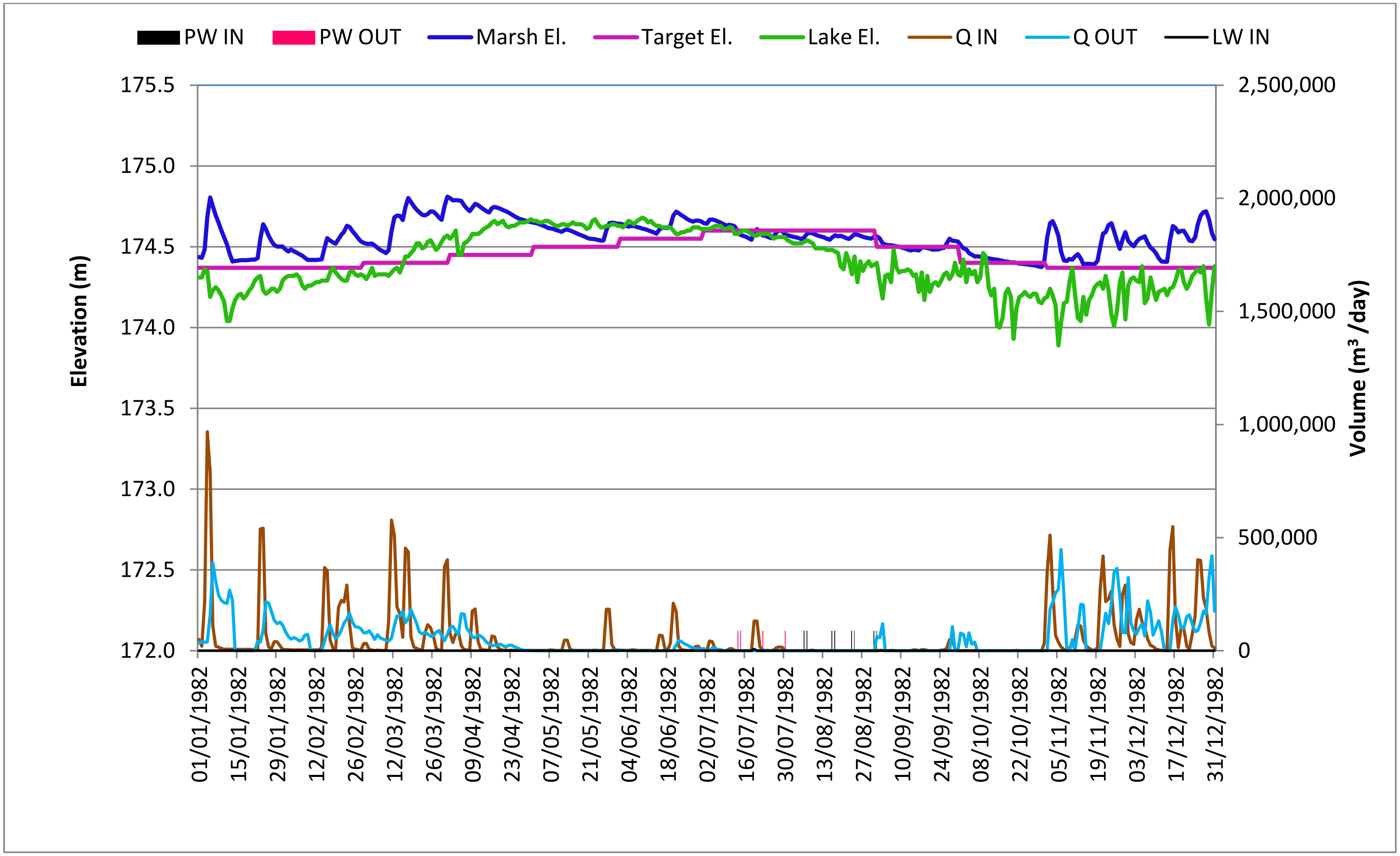


Figure 30: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in a Dry Year, 1982 Condition

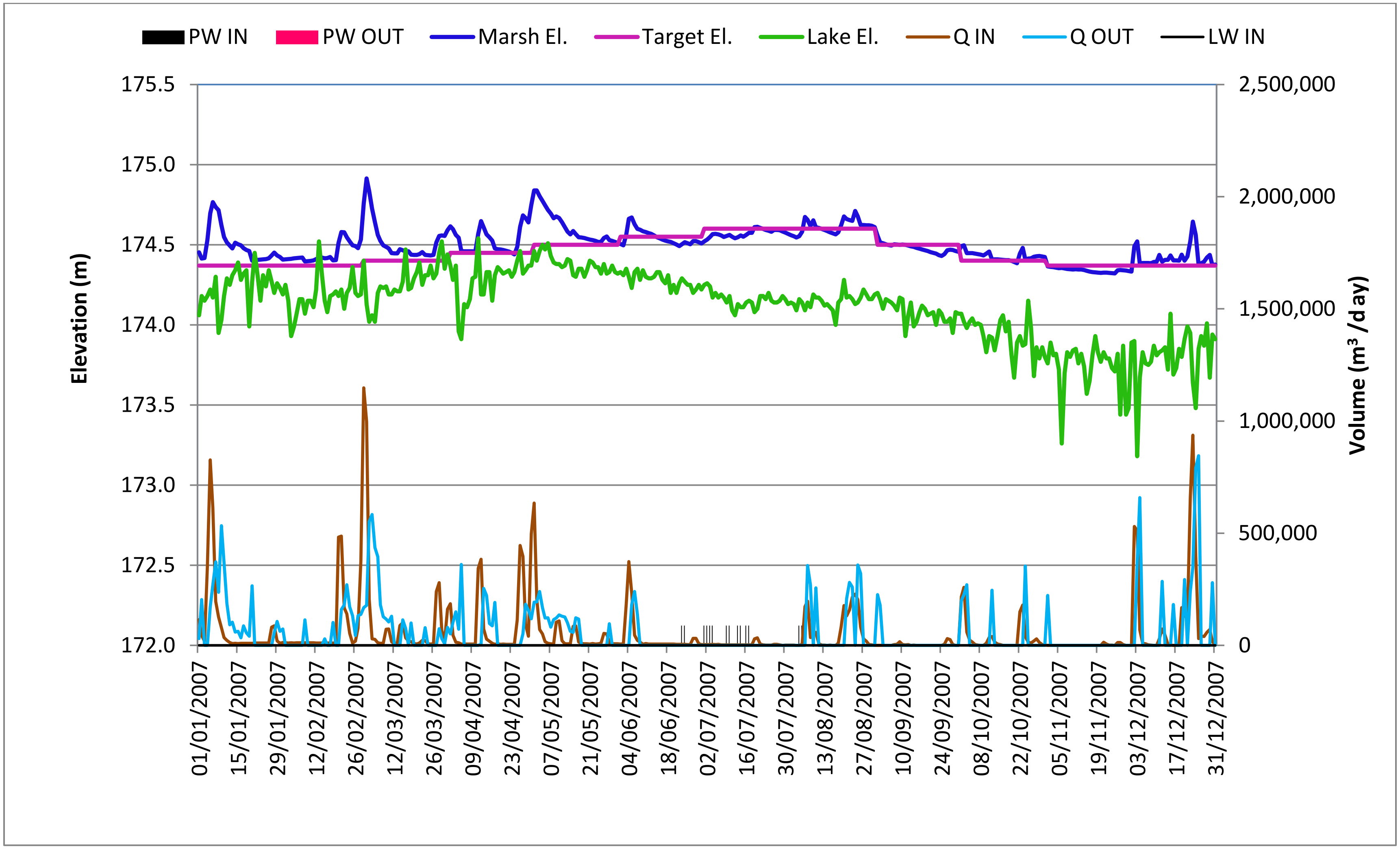


Figure 31: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in an Average Year, 2007 Condition

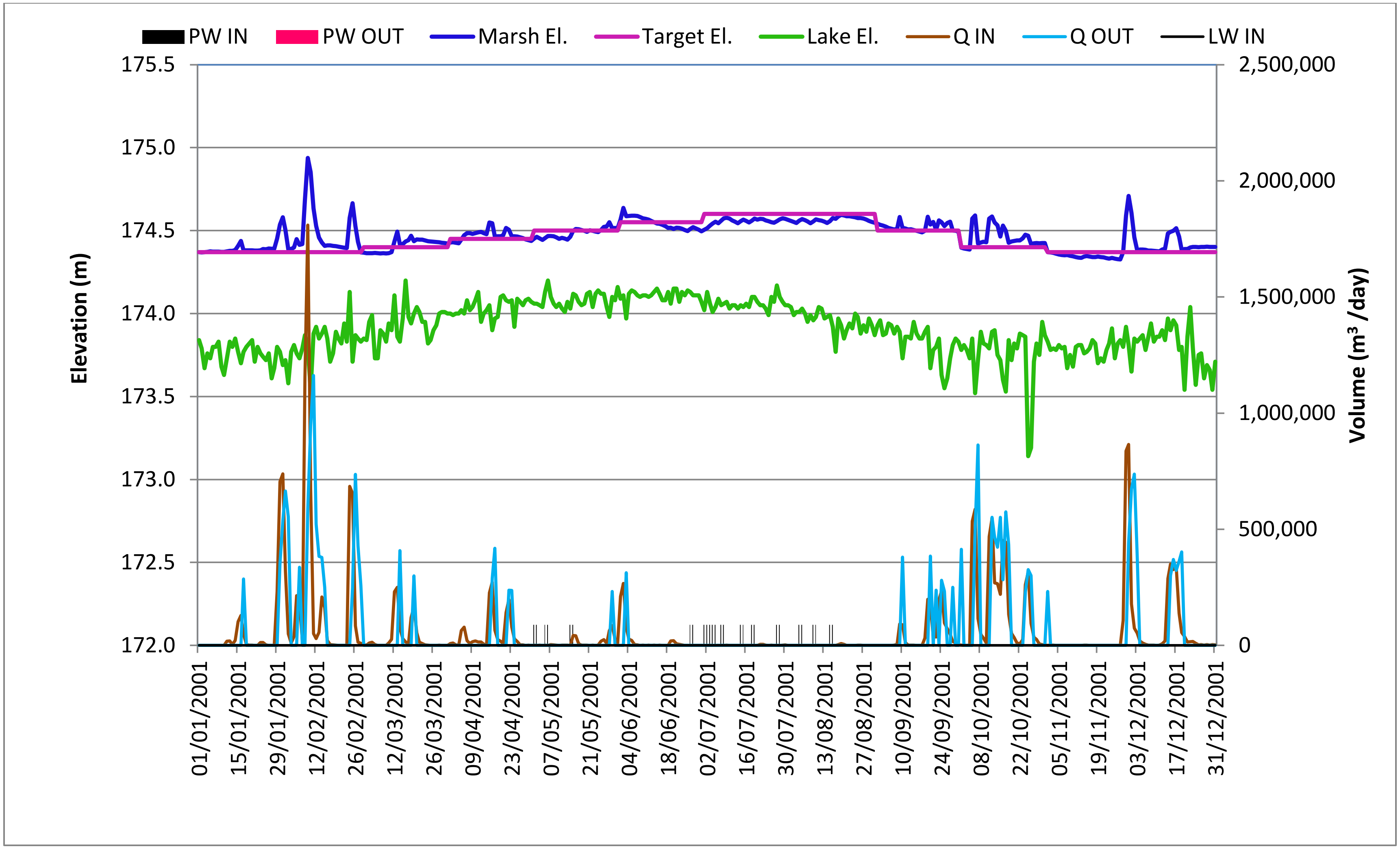


Figure 32: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in an Average Year, 2001 Condition

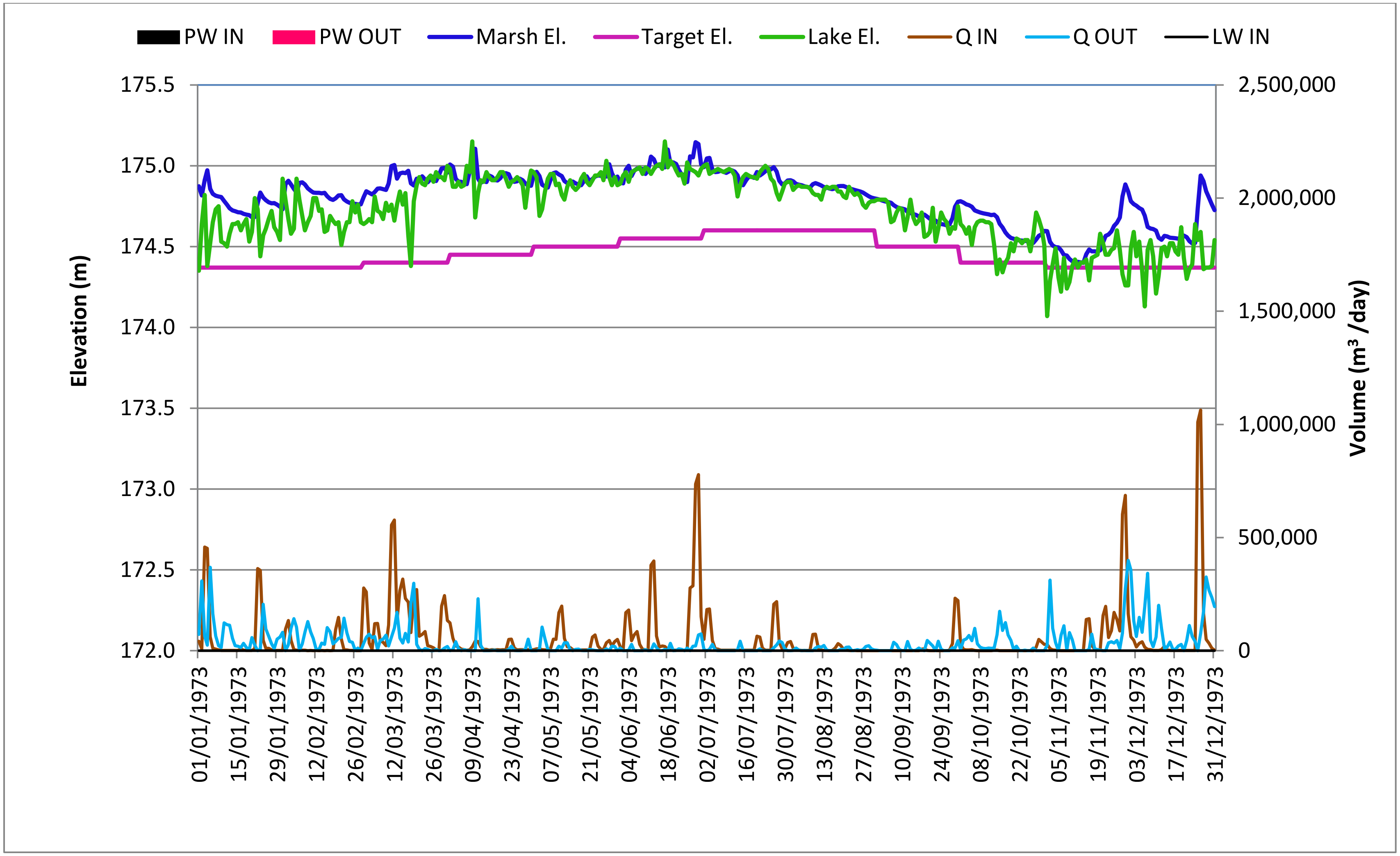


Figure 33: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in an Average Year, 1973 Condition

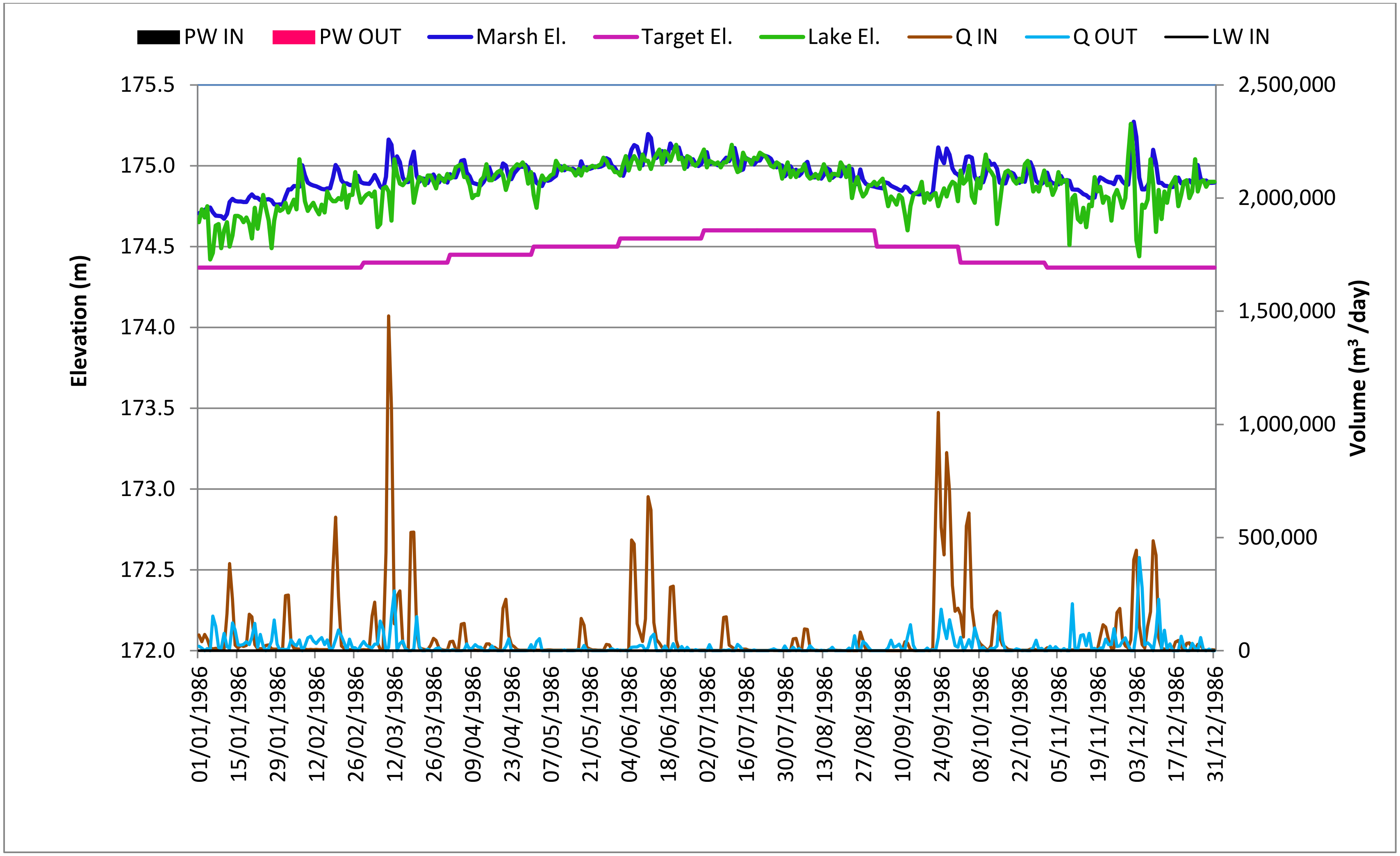


Figure 34: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in a Wet Year, 1986 Condition

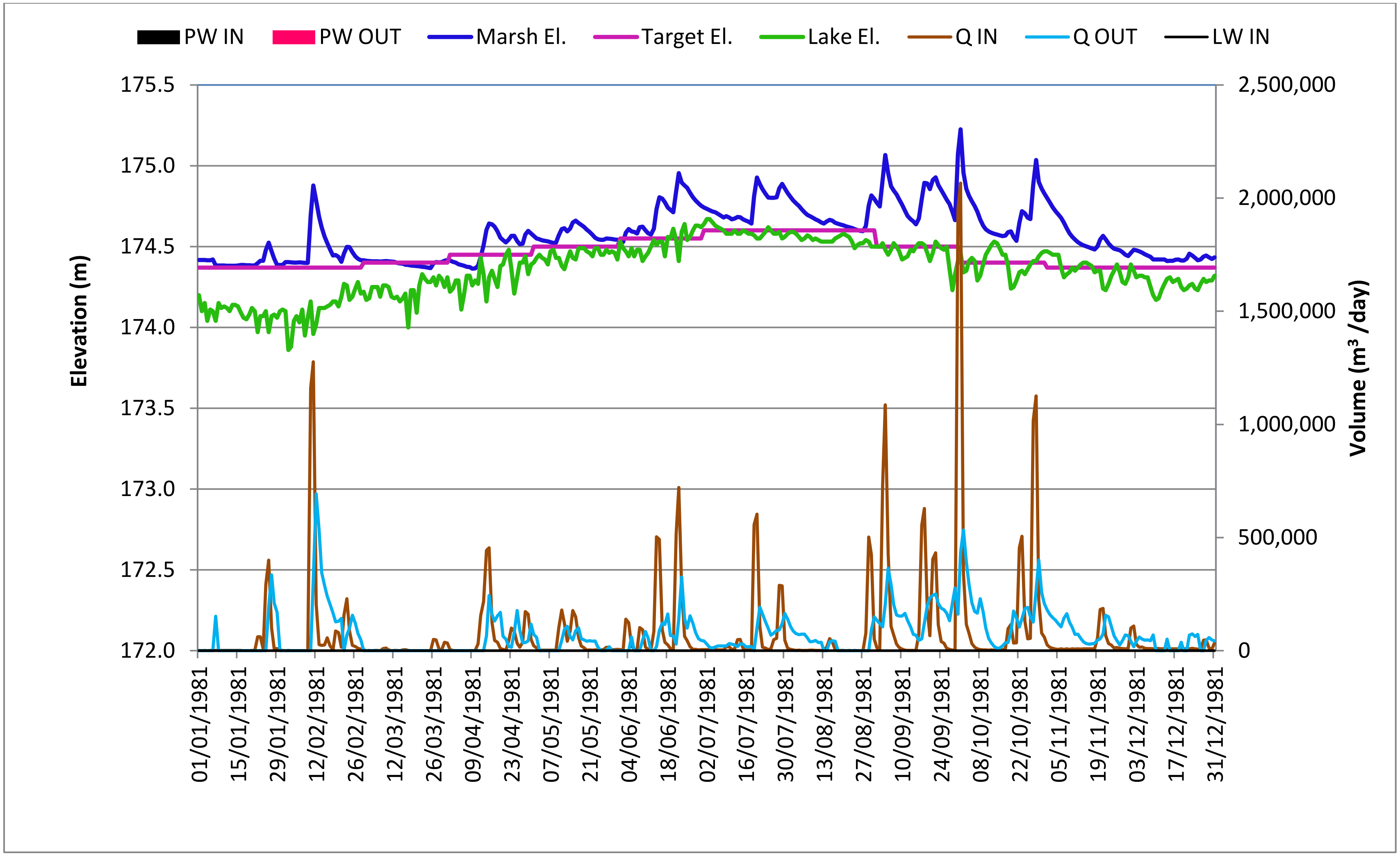


Figure 35: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in a Wet Year, 1981 Condition

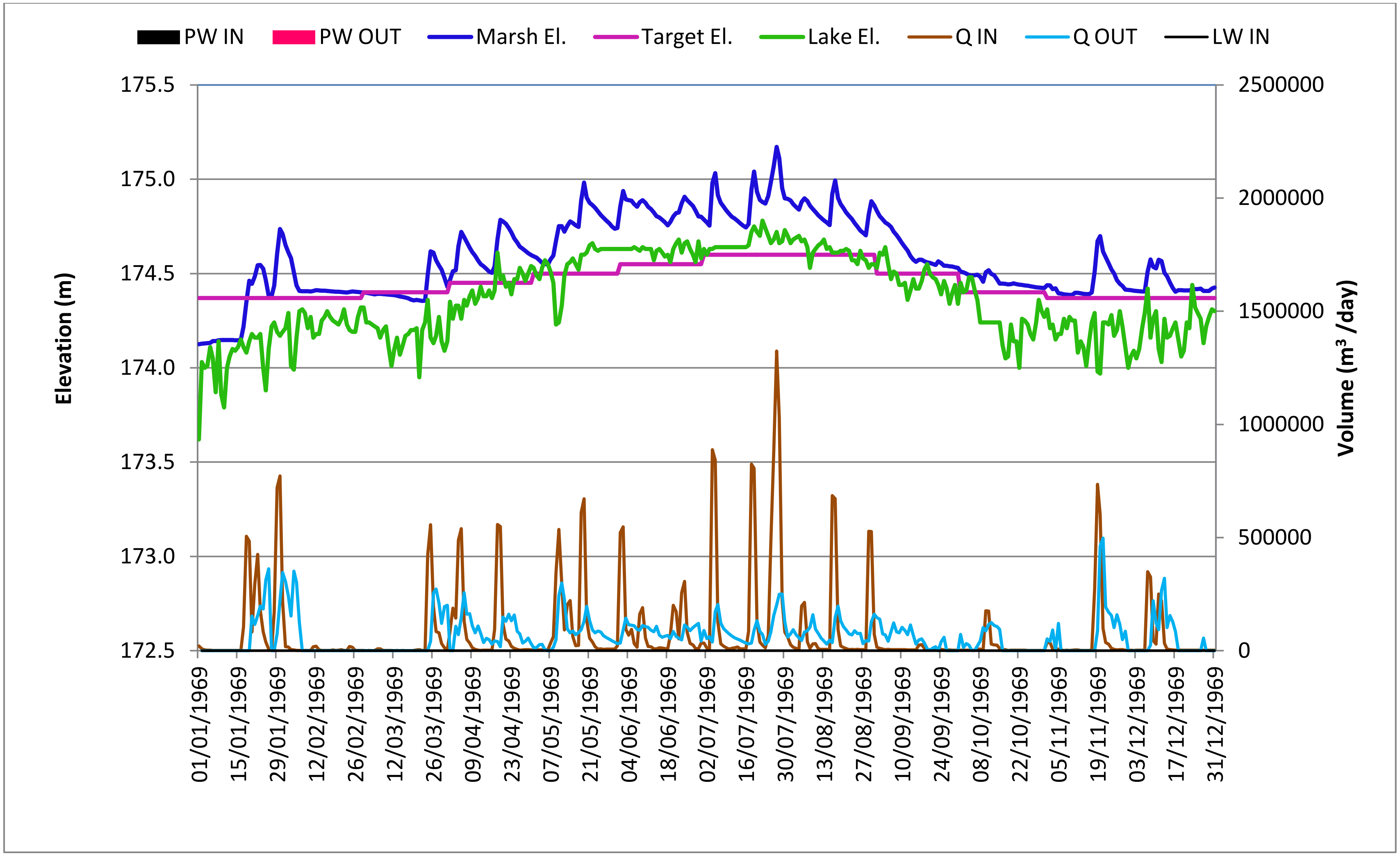


Figure 36: Daily Water Levels, flows and Pumping Water Plot for Overgrown Marsh in a Wet Year, 1969 Condition

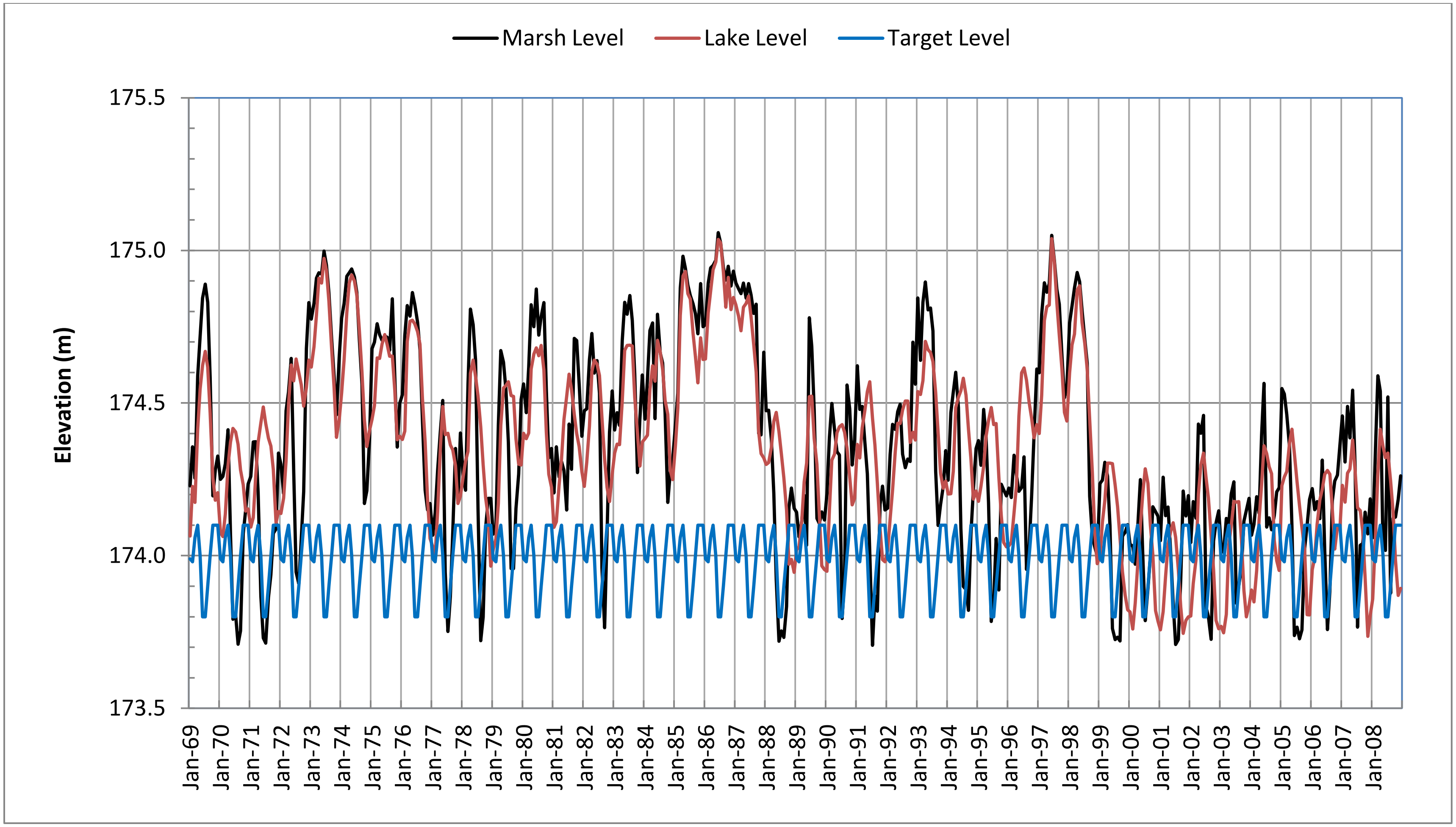


Figure 37: Monthly Average Marsh and Lake Levels during 1969 to 2008 and Target Levels for Open Water Marsh Phase

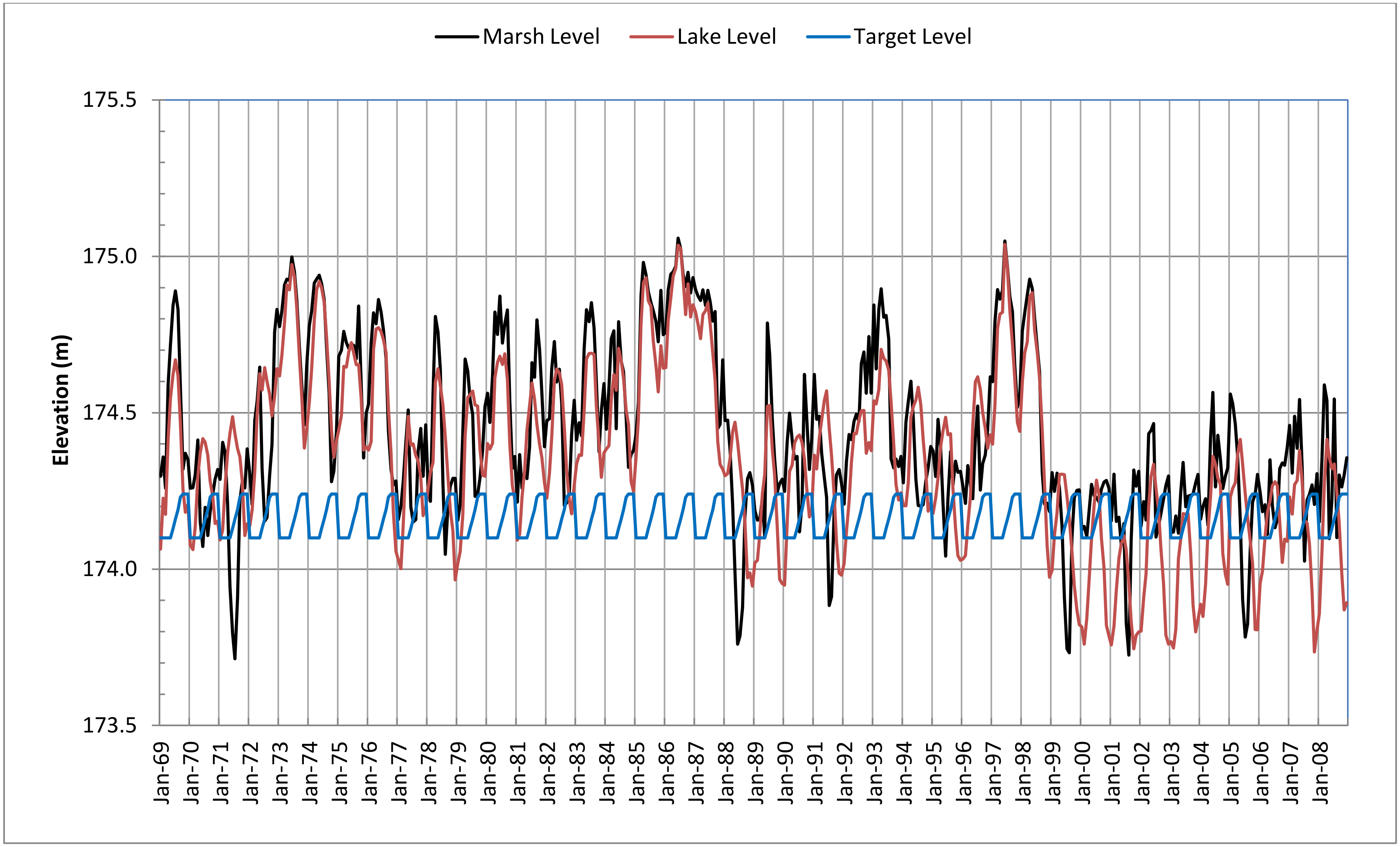


Figure 38: Monthly Average Marsh and Lake Levels during 1969 to 2008 and Target Levels for Open Water 2 Marsh Phase

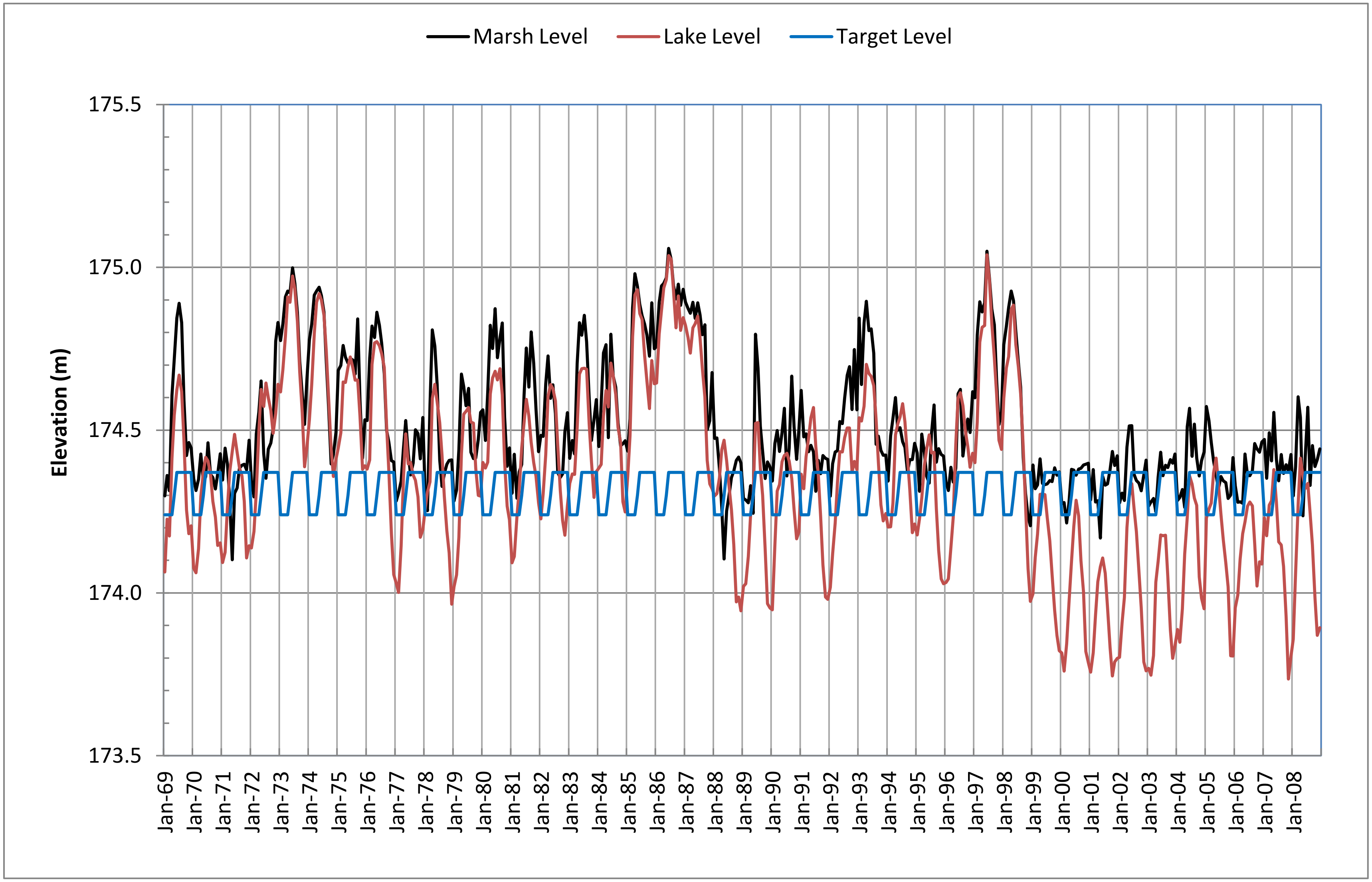


Figure 39: Monthly Average Marsh and Lake Levels during 1969 to 2008 and Target Levels for Hemi Marsh Phase

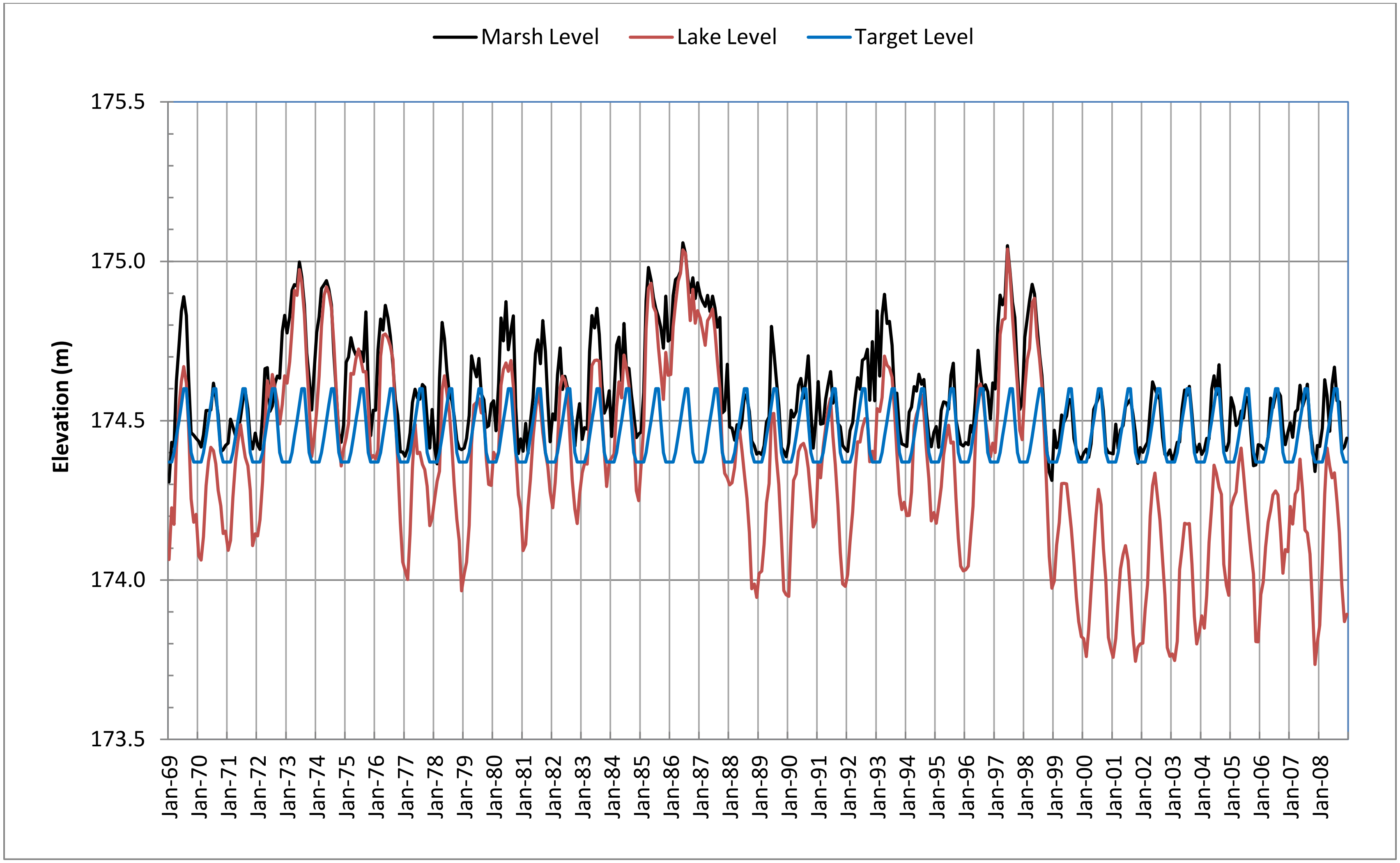


Figure 40: Monthly Average Marsh and Lake Levels during 1969 to 2008 and Target Levels for Overgrown Marsh Phase

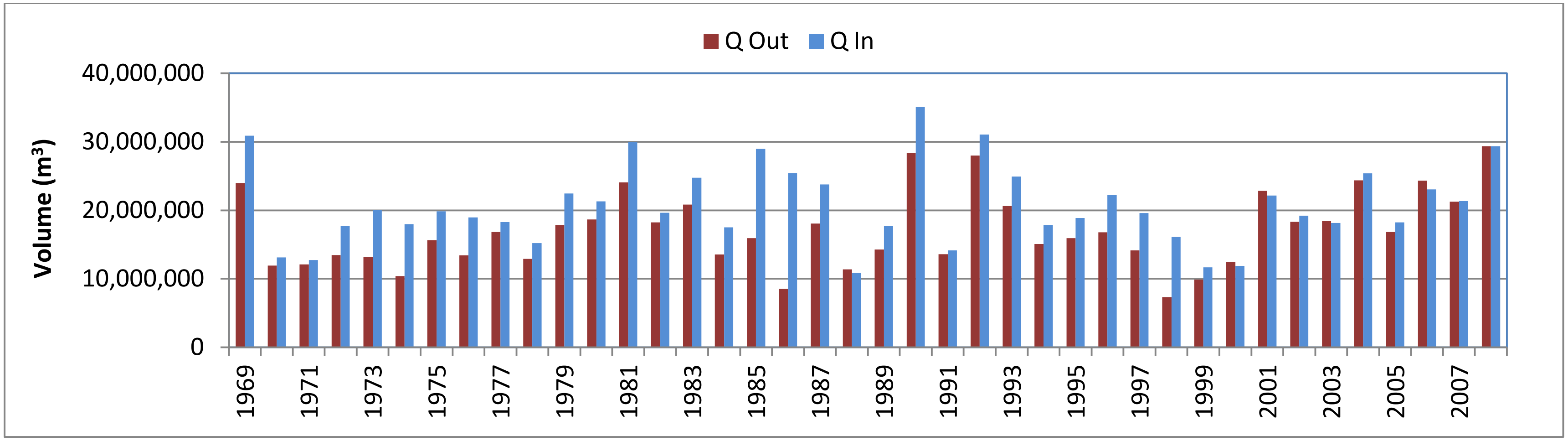


Figure 41: Streamflow Entered into and Water Released from the Marsh under Open Water Marsh Scenario

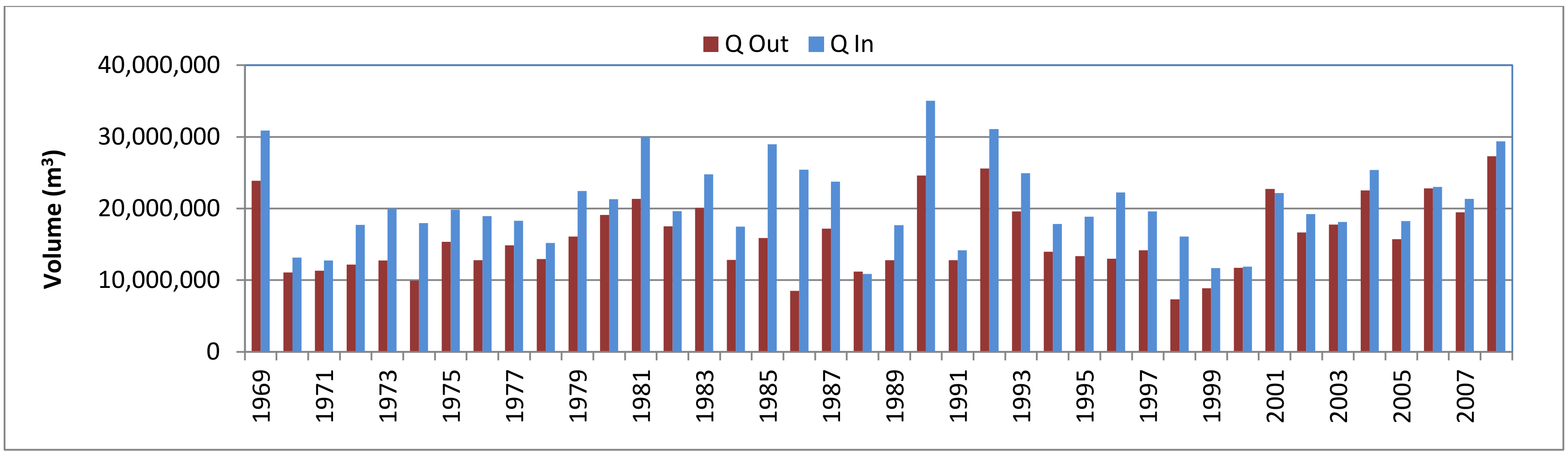


Figure 42: Streamflow Entered into and Water Released from the Marsh under Open Water 2 Marsh Scenario

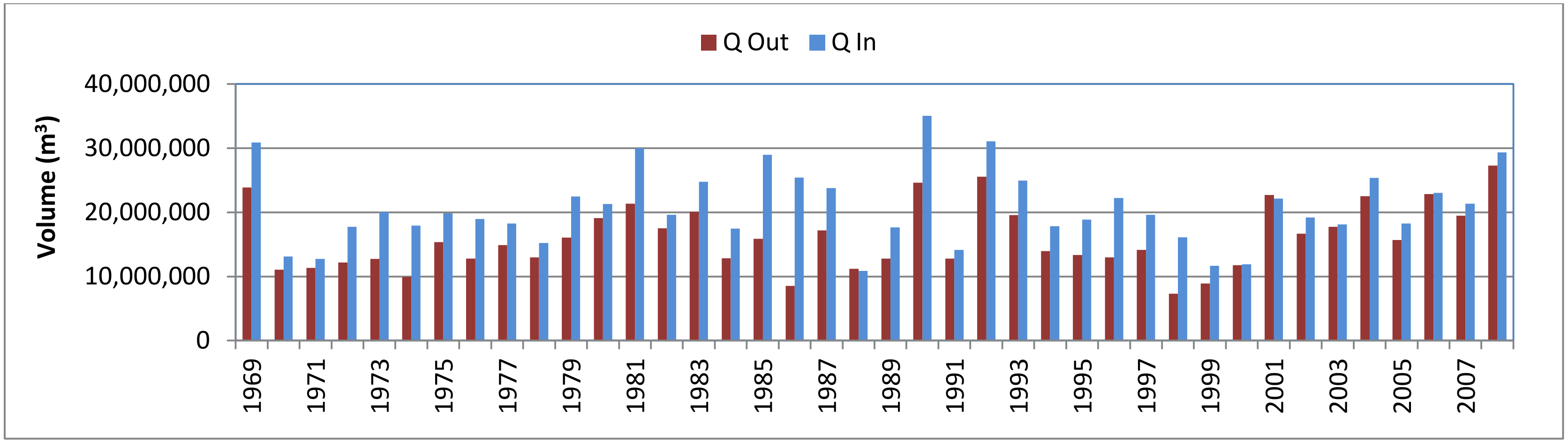


Figure 43: Streamflow Entered into and Water Released from the Marsh under Hemi Marsh Scenario

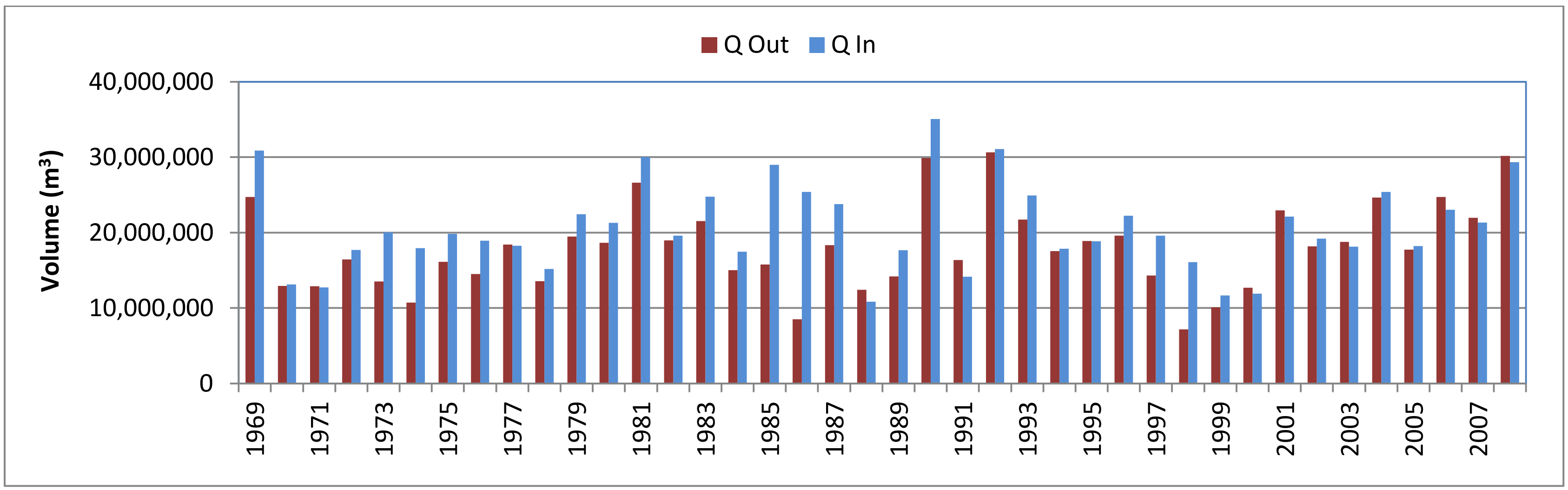


Figure 44: Streamflow Entered into and Water Released from the Marsh under Overgrown Marsh Scenario

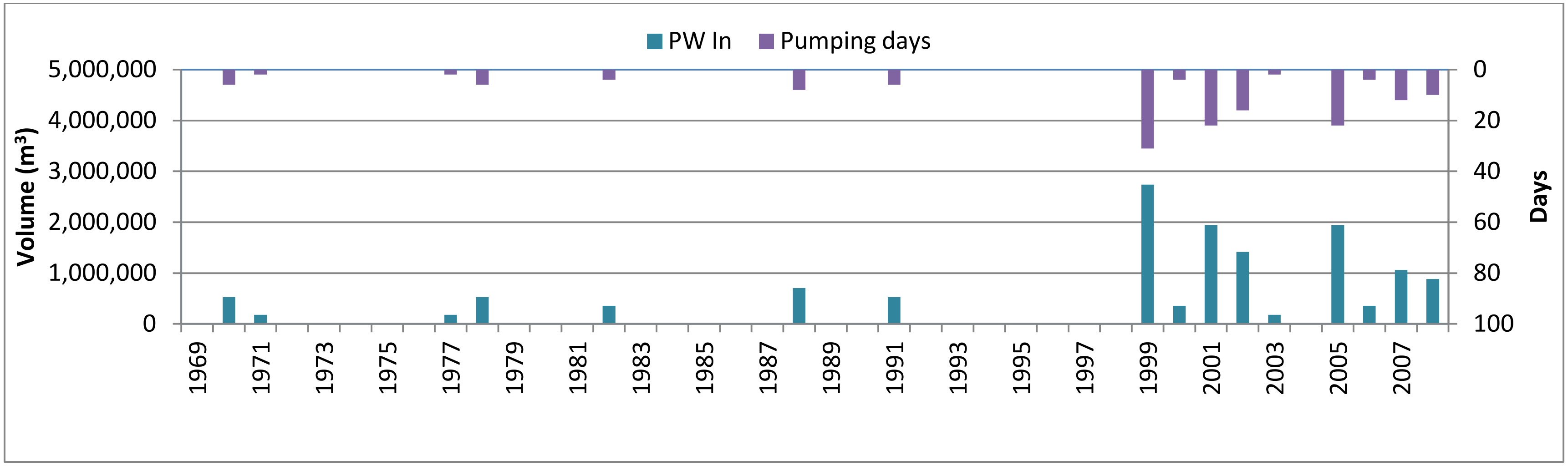


Figure 45: Water Quantity Pumped into the Marsh and Pumping Days under Open Water Marsh Scenario

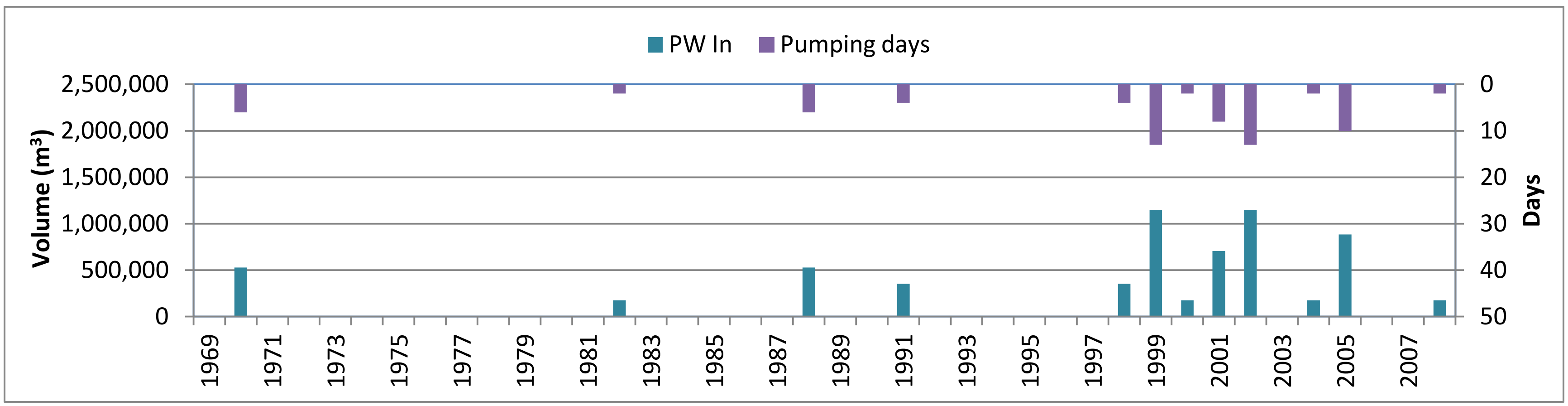


Figure 46: Water Quantity Pumped into the Marsh and Pumping Days under Open Water 2 Marsh Scenario

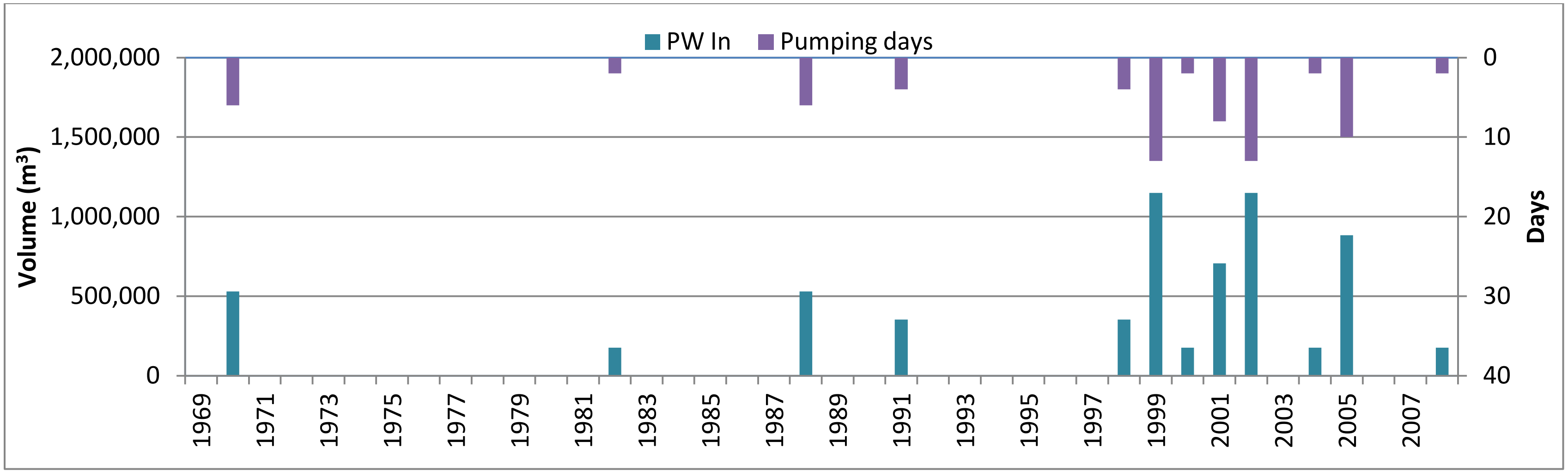


Figure 47: Water Quantity Pumped into the Marsh and Pumping Days under Hemi Marsh Scenario

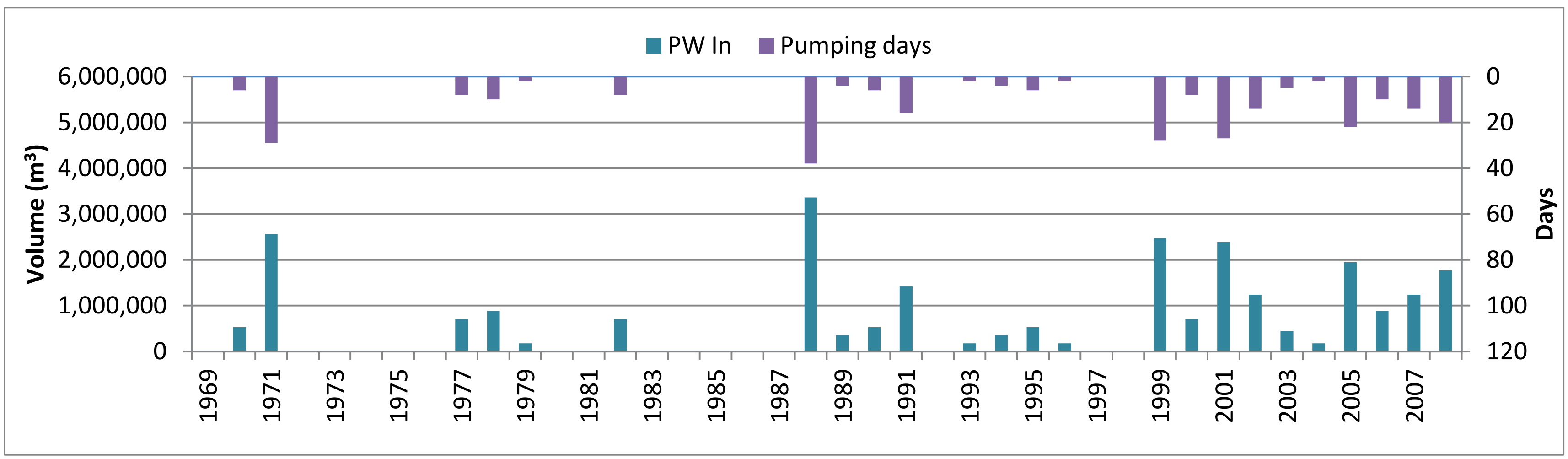


Figure 48: Water Quantity Pumped into the Marsh and Pumping Days under Overgrown Marsh Scenario

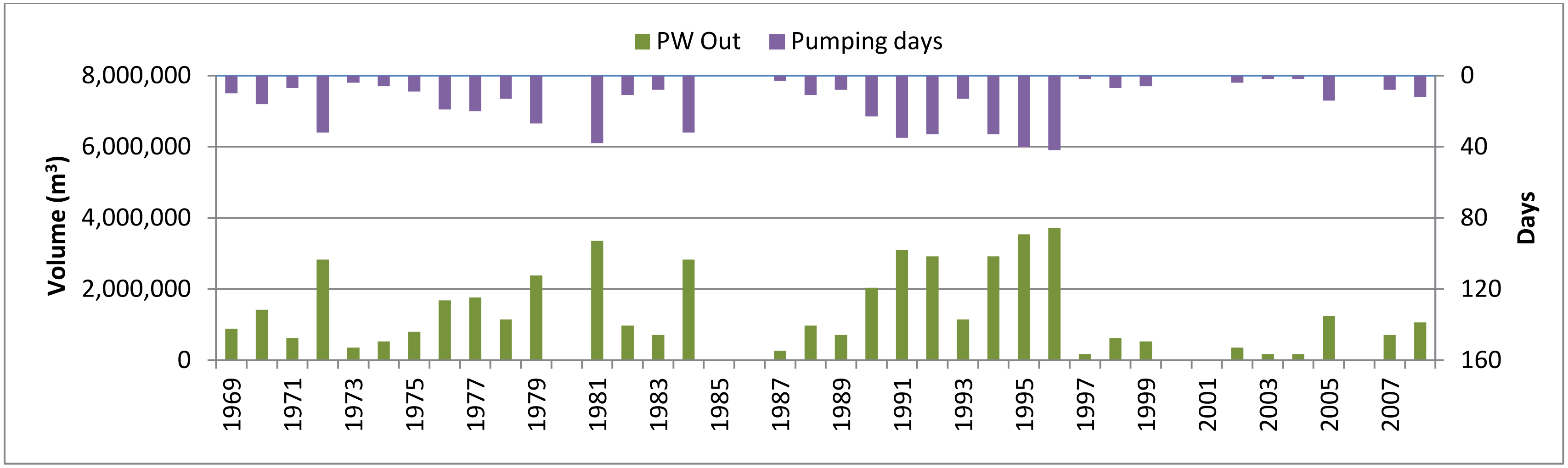


Figure 49: Water Quantity Pumped out from the Marsh and Pumping Days under Open Water Marsh Scenario

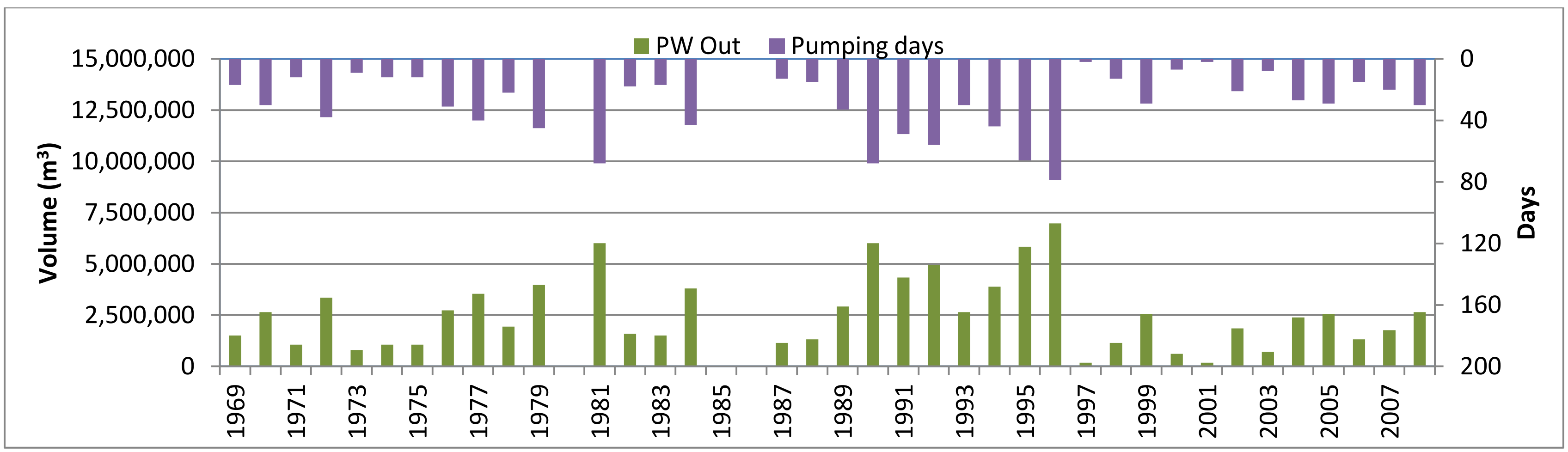


Figure 50: Water Quantity Pumped out from the Marsh and Pumping Days under Open Water 2 Marsh Scenario

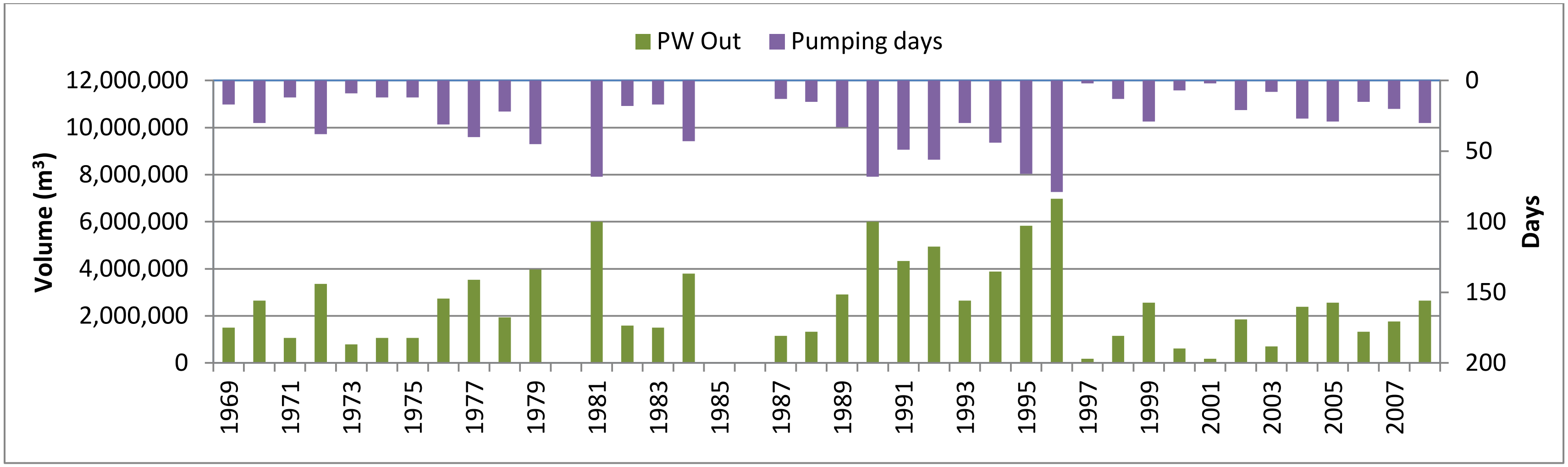


Figure 51: Water Quantity Pumped out from the Marsh and Pumping Days under Hemi Marsh Scenario

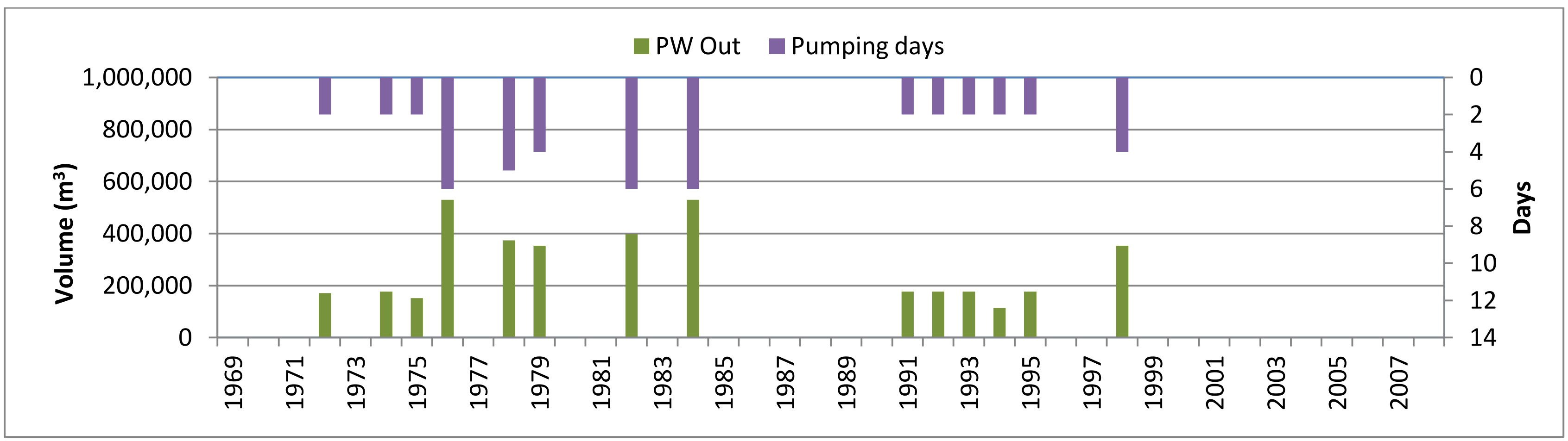


Figure 52: Water Quantity Pumped out from the Marsh and Pumping Days under Overgrown Scenario

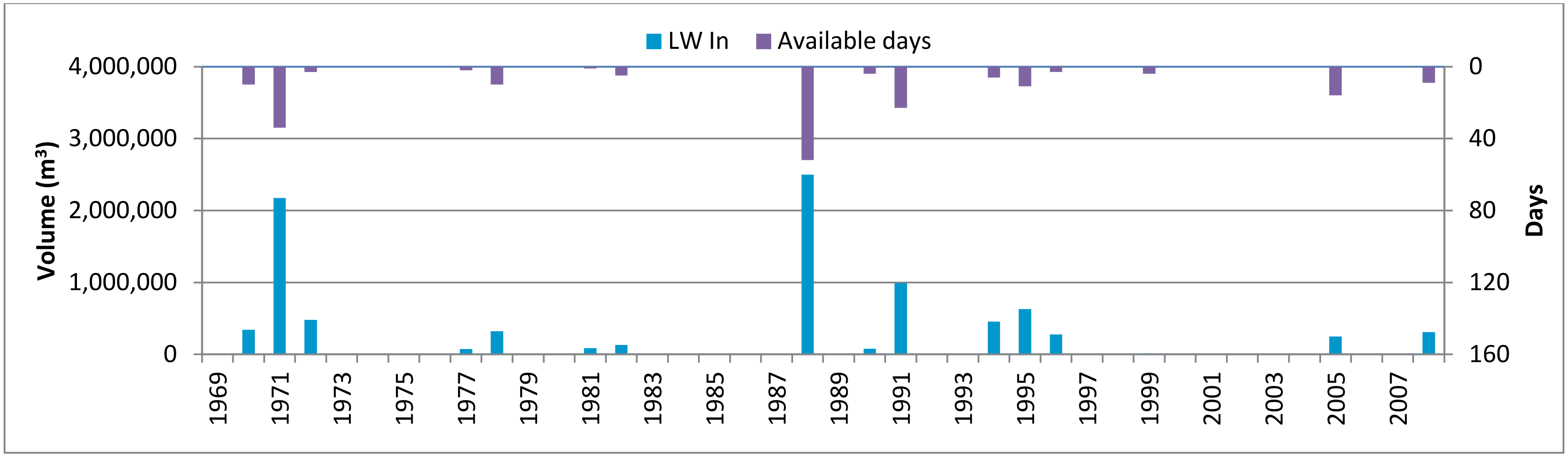


Figure 53: Lake Water Taken into the Marsh through the Gate and Available Days under Open Water Marsh Scenario

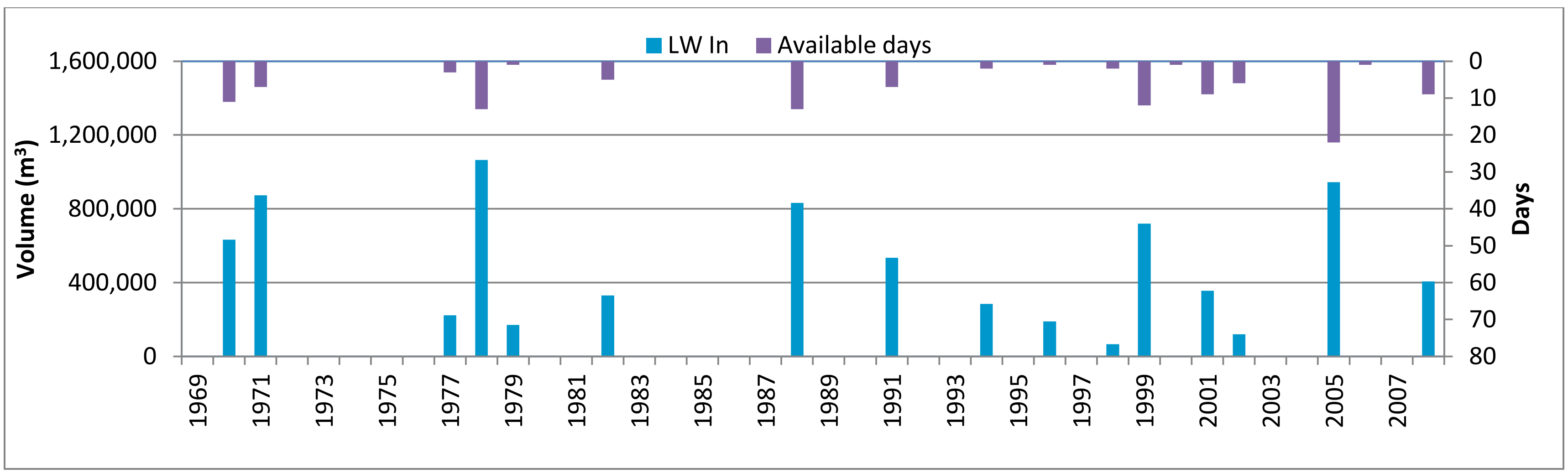


Figure 54: Lake Water Taken into the Marsh through the Gate and Available Days under Open Water 2 Marsh Scenario

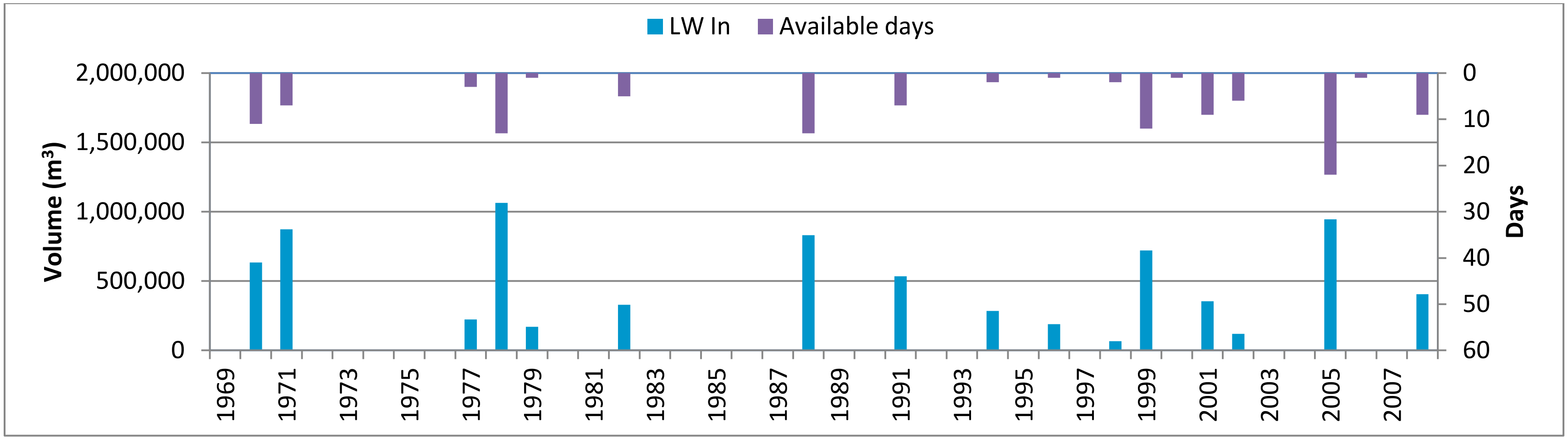


Figure 55: Lake Water Taken into the Marsh through the Gate and Available Days under Hemi Marsh Scenario

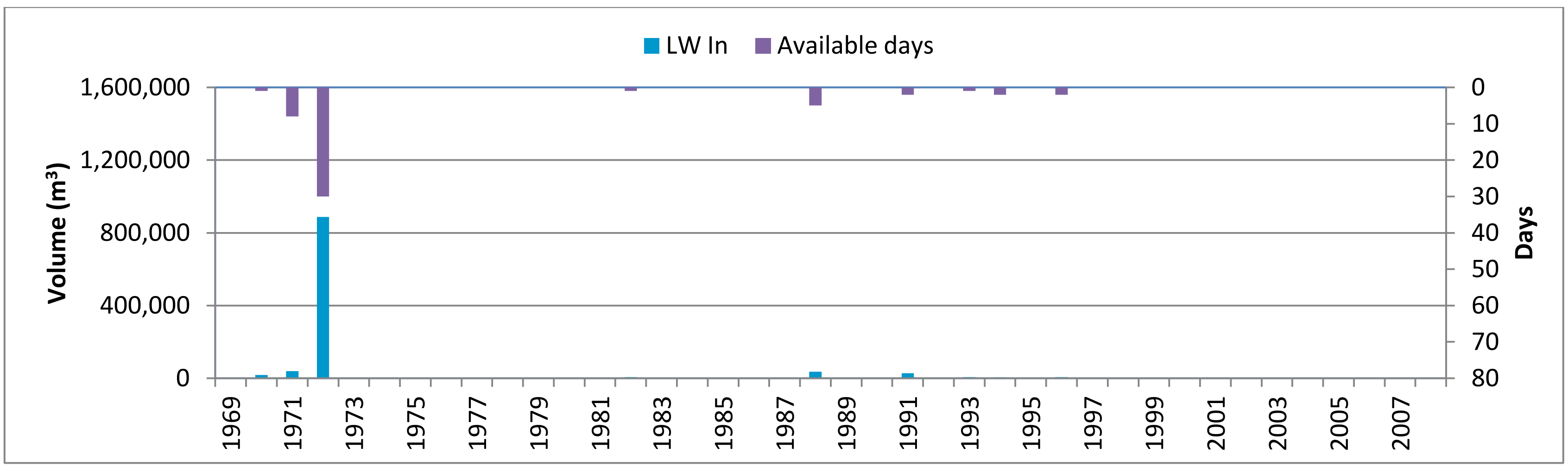


Figure 56: Lake Water Taken into the Marsh through the Gate and Available Days under Overgrown Marsh Scenario

Table 1: Target Marsh Depths above Basin Elevation of 173.80m GSC for Different Marsh Conditions

Month	Marsh Phase			
	Open water	Open water 2	Hemi	Overgrown
Jan	0.19	0.30	0.44	0.57
Feb	0.18	0.30	0.44	0.57
Mar	0.26	0.30	0.44	0.60
Apr	0.30	0.30	0.44	0.65
May	0.20	0.30	0.50	0.70
Jun	0.00	0.33	0.57	0.75
Jul	0.00	0.36	0.57	0.80
Aug	0.10	0.39	0.57	0.80
Sep	0.20	0.43	0.57	0.70
Oct	0.30	0.44	0.57	0.60
Nov	0.30	0.44	0.57	0.57
Dec	0.30	0.44	0.57	0.57

Table 2: Provision of Water Taking out of the Marsh by Pumping While Marsh Level Exceeds the Specified Elevation in the Select Months for Different Marsh Conditions

Month	Marsh Phase			
	Open water	Open water 2	Hemi	Overgrown
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	>174.15	>174.15	>174.29	>174.60
May	>174.05	>174.15	>174.35	>174.60
Jun	>173.85	>174.23	>174.47	>174.60
Jul	>173.85	>174.26	>174.47	>174.60
Aug	>174.00	>174.29	>174.47	>174.60
Sep	>174.10	>174.33	>174.47	>174.60
Oct	>174.20	>174.34	>174.47	>174.60
Nov	-	-	-	-
Dec	-	-	-	-

Table 3: Provisions of Water Taking into the Marsh by Pumping or Gravity Flow from the Lake during the Select Months for Different Marsh Conditions

Month	Marsh Phase			
	Open Water	Open water 2	Hemi	Overgrown
Jan				
Feb				
Mar				
Apr				
May				X
Jun			X	X
Jul			X	X
Aug			X	X
Sep		X	X	
Oct	X	X		
Nov				
Dec				

Table 4: Selected Dry, Average and Wet Years Based on Precipitation and Streamflow during the Months May to October

Hydrologic Condition	Year	Precipitation		Streamflow	
		Depth (mm)	Percent rank	Volume (m^3)	Percent rank
Dry year	2005	273	0%	1407772	5%
	1999	290	5%	514016	0%
	1982	322	13%	1856169	8%
Average year	2007	479	49%	5991071	46%
	2001	479	51%	7431766	59%
	1973	481	54%	6918614	49%
Wet year	1986	693	97%	12066541	85%
	1981	730	100%	21671580	100%
	1969	661	95%	18755424	97%

Table 5: Number of Days that the Lake Level was above 174.60m during 1969 to 2008

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sub-total	Total
1969	2	1	0	15	23	30	31	31	12	0	0	0	142	145
1970	0	0	0	5	0	0	0	0	0	0	0	0	5	5
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	6	14	25	0	0	0	0	0	23	31	39	99
1973	31	28	31	30	31	30	31	31	30	16	5	16	199	310
1974	31	28	31	30	31	30	31	31	17	0	0	0	170	260
1975	21	24	31	30	31	30	31	24	30	15	0	5	191	272
1976	7	24	31	30	31	30	31	30	0	0	0	0	152	214
1977	0	0	0	6	12	0	0	0	0	0	0	7	18	25
1978	0	0	17	30	31	21	0	0	0	0	0	0	82	99
1979	0	1	4	20	23	15	4	0	0	0	3	8	62	78
1980	12	0	15	30	31	30	31	31	30	7	0	0	190	217
1981	0	2	0	0	0	0	3	0	26	20	8	0	49	59
1982	5	2	20	30	17	27	12	0	0	0	0	5	86	118
1983	0	0	3	29	31	30	31	31	21	0	3	13	173	192
1984	0	10	17	30	4	30	29	14	6	0	0	0	113	140
1985	0	7	31	30	31	30	31	31	30	31	30	31	214	313
1986	31	28	31	30	31	30	31	31	30	31	30	31	214	365
1987	31	28	31	30	31	30	31	31	30	3	5	26	186	307
1988	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1989	0	0	0	0	1	30	21	6	0	0	0	0	58	58
1990	0	7	5	0	0	0	0	0	17	7	0	3	24	39
1991	21	2	0	2	0	0	0	0	0	0	0	0	2	25
1992	0	0	0	0	7	1	0	0	0	0	29	5	8	42
1993	31	20	30	30	31	30	31	1	0	0	0	0	123	204
1994	0	7	4	11	11	0	0	0	0	0	0	1	22	34
1995	2	0	7	0	0	0	0	0	0	1	0	0	1	10
1996	0	0	3	0	0	0	0	0	0	0	0	12	0	15
1997	20	28	31	30	31	30	31	31	30	26	0	8	209	296
1998	30	28	31	30	31	30	30	21	0	0	0	0	142	231
1999	6	0	0	0	0	0	0	0	0	0	0	0	0	6
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	2	0	0	0	0	0	0	0	0	0	0	0	2
2002	0	0	0	2	3	8	0	0	0	0	0	0	13	13
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	7	12	0	0	0	0	0	0	19	19
2005	8	7	0	0	0	0	0	0	0	0	0	0	0	15
2006	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2007	4	0	5	0	11	0	0	0	0	0	0	0	11	20
2008	0	3	15	9	0	0	11	0	1	0	0	0	21	39

Note: Sub-total is sum of the number of days from April to October

Table 6: Monthly Average Lake Level during 1969 to 2008

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969	174.23	174.36	174.25	174.59	174.72	174.84	174.89	174.83	174.58	174.20	174.28	174.33
1970	174.25	174.26	174.30	174.41	174.05	173.78	173.81	173.71	173.75	174.07	174.15	174.24
1971	174.26	174.37	174.37	174.19	173.83	173.73	173.71	173.86	173.94	174.07	174.09	174.34
1972	174.30	174.20	174.48	174.54	174.65	174.28	173.95	173.91	174.05	174.21	174.68	174.83
1973	174.78	174.83	174.91	174.93	174.92	175.00	174.95	174.86	174.71	174.59	174.46	174.65
1974	174.78	174.83	174.92	174.93	174.94	174.91	174.86	174.71	174.56	174.17	174.21	174.39
1975	174.68	174.70	174.76	174.72	174.71	174.72	174.72	174.67	174.84	174.59	174.36	174.50
1976	174.53	174.72	174.82	174.78	174.86	174.82	174.77	174.67	174.44	174.21	174.15	174.17
1977	174.07	174.14	174.28	174.40	174.51	173.95	173.75	173.87	174.08	174.35	174.17	174.40
1978	174.26	174.21	174.56	174.81	174.76	174.64	174.15	173.72	173.80	174.09	174.19	174.19
1979	174.07	174.10	174.43	174.67	174.63	174.54	174.37	173.96	173.96	174.16	174.27	174.51
1980	174.56	174.47	174.62	174.82	174.75	174.87	174.72	174.78	174.83	174.54	174.32	174.35
1981	174.21	174.36	174.26	174.28	174.21	174.12	174.42	174.27	174.71	174.70	174.56	174.39
1982	174.48	174.48	174.64	174.73	174.60	174.64	174.53	173.96	173.76	174.07	174.40	174.54
1983	174.41	174.47	174.43	174.70	174.83	174.79	174.85	174.77	174.60	174.27	174.45	174.59
1984	174.45	174.58	174.74	174.76	174.45	174.79	174.67	174.63	174.47	174.17	174.27	174.32
1985	174.43	174.53	174.88	174.98	174.94	174.89	174.85	174.83	174.79	174.73	174.89	174.75
1986	174.76	174.89	174.94	174.95	174.97	175.06	175.02	174.94	174.90	174.95	174.88	174.93
1987	174.89	174.87	174.86	174.89	174.84	174.89	174.85	174.79	174.82	174.40	174.40	174.67
1988	174.47	174.48	174.38	174.18	173.88	173.72	173.75	173.73	173.83	174.16	174.22	174.15
1989	174.14	174.06	174.11	174.18	174.01	174.78	174.68	174.48	174.12	174.10	174.14	174.12
1990	174.20	174.39	174.50	174.41	174.34	174.33	173.79	173.92	174.56	174.48	174.30	174.38
1991	174.62	174.48	174.49	174.36	174.25	174.00	173.71	173.87	173.82	174.17	174.23	174.15
1992	174.16	174.33	174.43	174.41	174.47	174.50	174.33	174.29	174.32	174.31	174.70	174.56
1993	174.84	174.64	174.83	174.90	174.81	174.81	174.74	174.28	174.10	174.17	174.23	174.34
1994	174.25	174.47	174.54	174.60	174.49	174.09	173.90	173.89	173.82	174.07	174.21	174.35
1995	174.38	174.30	174.48	174.39	174.16	173.77	173.85	174.06	173.89	174.23	174.22	174.20
1996	174.22	174.19	174.33	174.25	174.19	174.21	174.31	173.99	174.05	174.20	174.40	174.61
1997	174.60	174.79	174.89	174.86	174.89	175.05	174.97	174.87	174.82	174.65	174.52	174.56
1998	174.76	174.82	174.88	174.93	174.90	174.80	174.71	174.63	174.19	174.06	174.03	174.00
1999	174.24	174.25	174.31	174.25	174.06	173.75	173.73	173.73	173.72	174.06	174.08	174.10
2000	174.04	174.03	173.97	174.09	174.25	174.00	173.79	173.89	174.00	174.16	174.14	174.13
2001	174.05	174.26	174.13	174.16	173.96	173.84	173.71	173.73	173.92	174.21	174.13	174.20
2002	174.04	174.18	174.12	174.43	174.39	174.46	173.83	173.80	173.73	174.05	174.11	174.15
2003	174.03	174.01	174.12	174.09	174.19	174.23	173.84	173.90	173.96	174.11	174.15	174.19
2004	174.07	174.10	174.19	174.13	174.37	174.56	174.09	174.12	174.08	174.13	174.21	174.22
2005	174.55	174.53	174.46	174.36	174.07	173.73	173.77	173.73	173.76	174.02	174.10	174.18
2006	174.22	174.15	174.18	174.10	174.30	174.02	173.76	173.88	174.18	174.24	174.26	174.36
2007	174.46	174.31	174.49	174.39	174.54	174.29	173.77	174.03	174.04	174.14	174.07	174.19
2008	174.06	174.35	174.59	174.54	174.00	173.99	174.52	173.88	174.12	174.13	174.18	174.26

Table 7: Number of Days that Marsh Level Remained within ± 0.10m Limit from the Target Level for the Open Water Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	15		7							19	17		58	9%
1970			2	3	21	27	29			28	26	13	149	50%
1971	5	3		18	12	30	31	20	24	31	30	5	209	78%
1972							9	3	23	21			56	26%
1973														0%
1974										26	14		40	12%
1975														0%
1976										19	26	26	71	9%
1977	20	9	2	8		12	31	26	2	4	27	4	145	39%
1978							8		3	29	16	18	74	19%
1979	27	21						26	24	31	21		150	38%
1980														0%
1981				11	4	4		3					22	10%
1982								17	4	31			52	24%
1983										7	1		8	3%
1984										26	8	7	41	12%
1985														0%
1986														0%
1987														0%
1988				17	22	30	28	2	9	23	13	24	168	61%
1989	5	16	27	19	27				13	31	27	30	195	42%
1990	8						27	9	2				46	18%
1991				7	6	12	31	18	6	21	18	28	147	47%
1992	10								4	3			17	3%
1993								6	17	22	16		61	21%
1994						5	19	14	1	31	13	5	88	33%
1995					8	25	23	11	11	16	14	20	128	44%
1996	3			8	8	4		15	10	21			69	31%
1997														0%
1998									14	31	29	15	89	21%
1999	17			13	21	28	31	5		26	30	31	202	58%
2000	30	25	21	1	1	12	27	29	18	24	26	29	243	52%
2001	28	6	21	24	29	20	31	1	20	18	28	20	246	67%
2002	28	4	25		3		22	15		25	30	25	177	30%
2003	24	27	24	29	9		22	31	24	28	27	21	266	67%
2004	25	19	15	25	7		6	9	19	23	17	19	184	42%
2005				4	22	29	27	2		21	27	25	156	49%
2006	2	3	14	30	9	12	31	28	11	11	7	2	160	62%
2007				1		1	31	7	26	30	30	24	150	45%
2008	28				23	12		17		30	21	10	141	38%

Table 8: Number of Days that Marsh Level Remained within ± 0.15m Limit from the Target Level for the Open Water Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	17		12							23	17	3	72	11%
1970	6		3	4	26	29	31	1		30	27	14	171	57%
1971	5	4	1	20	15	30	31	24	30	31	30	5	226	85%
1972		7		2			15	18	28	21			91	39%
1973														0%
1974										27	23		50	13%
1975														0%
1976										22	26	31	79	10%
1977	31	11	6	10		14	31	27	14	6	29	7	186	48%
1978			6				9	5	11	30	21	24	106	26%
1979	28	22						28	28	31	22		159	41%
1980														0%
1981		5	8	12	7	7		5					44	14%
1982								22	5	31			58	27%
1983										13	2		15	6%
1984										31	12	10	53	14%
1985														0%
1986														0%
1987										7			7	3%
1988				19	26	30	31	8	9	23	18	29	193	68%
1989	18	28	31	21	29				20	31	28	31	237	47%
1990	12				1		28	18	5		6	10	80	24%
1991				9	9	13	31	21	14	22	22	30	171	56%
1992	13								5	8			26	6%
1993								7	25	27	20	5	84	28%
1994						6	20	19	10	31	16	6	108	40%
1995				3	16	26	25	17	27	18	22	23	177	62%
1996	8	8	8	15	9	7		22	15	26	6		124	44%
1997														0%
1998									15	31	30	31	107	21%
1999	19		2	21	22	30	31	8	1	29	30	31	224	66%
2000	31	28	31	12	6	14	28	31	25	27	28	31	292	67%
2001	29	9	29	28	31	21	31	7	22	20	28	22	277	75%
2002	29	9	27	3	7		24	19		27	30	27	202	37%
2003	27	28	26	30	12		25	31	30	29	30	24	292	73%
2004	25	21	18	27	8		11	13	21	28	20	20	212	50%
2005				7	23	30	29	8		27	28	27	179	58%
2006	12	14	22	30	9	14	31	30	14	18	17	4	215	68%
2007				3		2	31	11	28	31	30	25	161	50%
2008	28				26	13		20		31	23	12	153	42%

Table 9: Number of Days that Marsh Level Remained within ± 0.20m Limit from the Target Level for the Open Water Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	17		21							30	18	17	103	14%
1970	9	5	9	6	31	30	31	31	2	30	30	23	237	75%
1971	5	4	6	21	23	30	31	31	30	31	30	13	255	92%
1972		7		4			21	30	30	22			114	50%
1973														0%
1974										29	30	1	60	14%
1975														0%
1976										26	30	31	87	12%
1977	31	17	16	12	3	17	31	31	24	8	30	13	233	59%
1978	2		10				10	31	17	31	29	29	159	42%
1979	29	22						30	30	31	22		164	43%
1980											10	12	22	0%
1981	16	7	17	13	8	11		7					79	18%
1982								24	5	31	5		65	28%
1983										19	9		28	9%
1984									1	31	23	14	69	15%
1985														0%
1986														0%
1987										12	6		18	6%
1988				21	28	30	31	31	10	30	24	31	236	85%
1989	24	28	31	23	29				28	31	29	31	254	52%
1990	15	2		2	3		29	30	5		20	17	123	32%
1991				13	14	14	31	29	17	23	22	31	194	66%
1992	21	5		5					7	16			54	13%
1993								9	28	31	25	7	100	32%
1994	5				2	8	22	28	22	31	30	10	158	53%
1995	4			7	18	29	28	20	30	20	28	25	209	71%
1996	15	16	14	18	13	10		23	18	29	6		162	52%
1997														0%
1998									17	31	30	31	109	22%
1999	21	12	8	21	24	30	31	31	2	30	30	31	271	79%
2000	31	29	31	24	11	15	29	31	30	31	29	31	322	80%
2001	29	11	31	30	31	22	31	31	22	22	28	25	313	88%
2002	30	18	28	6	9		26	31	3	28	30	29	238	48%
2003	30	28	28	30	14		28	31	30	30	30	28	307	76%
2004	26	23	19	29	9		13	15	23	30	24	22	233	56%
2005				9	25	30	31	31	6	29	30	27	218	75%
2006	15	22	27	30	9	17	31	31	16	21	22	10	251	72%
2007				6		3	31	21	29	31	30	27	178	57%
2008	28		1	2	28	16		29	2	31	25	22	184	50%

Table 10: Number of Days that Marsh Level Remained within ± 0.10m Limit from the Target Level for the Open Water I Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	16		12							23	17	18	86	11%
1970	10	8	2	3	25	26	28	16	27	31	27	23	226	73%
1971	5	3	1	18	9				29	31	30	14	140	41%
1972	6	10				12	31	15	23	18			115	46%
1973											5		5	0%
1974										31	19		50	14%
1975											13	4	17	0%
1976									1	23	27	30	81	11%
1977	30	17	3	8	3	22	31	29	13	9	29	11	205	54%
1978	9						18	6	21	31	26	25	136	36%
1979	28	22					7	28	29	31	21	2	168	44%
1980											23	17	40	0%
1981	15	7	5	11	8	12						1	59	14%
1982								31	30	31	8		100	43%
1983										13	1		14	6%
1984									6	27	16	13	62	15%
1985														0%
1986														0%
1987										6	5		11	3%
1988				17	16				16	26	21	28	124	35%
1989	22	26	29	14	27			2	14	31	28	30	223	41%
1990	14	2			3	7	31	14	5	5	23	17	121	30%
1991				7	10	19	1	8	29	24	21	30	149	46%
1992	18	7					9						34	4%
1993								15	18	15	20	10	78	22%
1994	5				2	12	22	24	30	31	18	11	155	57%
1995	5				15	18	23	10	30	20	22	24	167	54%
1996	6	16	8	8	13	8		22	17	17	6		121	40%
1997														0%
1998									22	31	30	31	114	25%
1999	19	12		13	24	2			14	31	30	31	176	39%
2000	31	27	31	19	9	21	24	30	28	27	28	31	306	74%
2001	28	11	27	24	31	24			17	22	28	23	235	55%
2002	29	15	25		8	4	19	25	23	31	30	26	235	51%
2003	26	28	24	30	13	2	28	31	30	29	29	23	293	76%
2004	25	22	17	25	8		18	2	15	27	24	22	205	44%
2005				4	25	5			8	31	28	27	128	34%
2006	14	21	20	30	9	23	31	30	20	19	22	10	249	76%
2007				1		10	9	13	30	30	30	26	149	43%
2008	27				27	10	3	18	9	31	23	18	166	46%

Table 11: Number of Days that Marsh Level Remained within ± 0.15m Limit from the Target Level for the Open Water 1 Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	17		16						2	27	18	21	101	14%
1970	15	13	7	4	27	30	31	26	28	31	30	25	267	83%
1971	10	4	5	20	14			4	30	31	30	17	165	46%
1972	10	21		2		16	31	24	28	21			153	57%
1973										3	14		17	1%
1974									2	31	30	3	66	15%
1975											24	5	29	0%
1976									8	25	30	31	94	15%
1977	31	22	15	10	4	28	31	31	15	14	30	13	244	62%
1978	19	28	10				20	20	29	31	30	31	218	47%
1979	28	22					8	30	30	31	22	12	183	46%
1980											28	23	51	0%
1981	23	9	16	12	10	13						20	103	16%
1982							1	31	30	31	13	2	108	43%
1983										20	7		27	9%
1984									10	31	22	14	77	19%
1985														0%
1986														0%
1987										11	11		22	5%
1988				19	24				20	29	27	31	150	43%
1989	28	28	31	18	29			7	17	31	28	31	248	48%
1990	17	11			5	10	31	31	5	7	27	18	162	42%
1991				9	14	21	8	12	30	24	23	31	172	55%
1992	24	13					12						49	6%
1993								17	26	22	25	21	111	30%
1994	16				3	12	28	29	30	31	29	17	195	62%
1995	8	13		3	23	22	30	17	30	21	27	27	221	68%
1996	13	22	11	15	17	11		24	21	23	6		163	52%
1997														0%
1998									24	31	30	31	116	26%
1999	21	14	7	21	25	6			17	31	30	31	203	47%
2000	31	29	31	21	14	23	26	31	30	30	29	31	326	82%
2001	29	13	30	28	31	28			19	23	28	25	254	60%
2002	30	19	27	2	10	5	30	31	26	31	30	28	269	63%
2003	30	28	26	30	14	10	31	31	30	30	30	27	317	82%
2004	27	23	18	27	9		26	8	18	31	27	22	236	56%
2005				7	26	8	3		10	31	30	27	142	40%
2006	16	23	23	30	9	26	31	31	21	23	25	18	276	80%
2007		14		3		13	14	17	30	31	30	27	179	50%
2008	28	5	1		31	20	4	22	13	31	26	23	204	57%

Table 12: Number of Days that Marsh Level Remained within ± 0.20m Limit from the Target Level for the Open Water I Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	17	10	23						5	31	23	24	133	17%
1970	23	20	14	6	31	30	31	31	29	31	30	26	302	88%
1971	19	5	6	21	20			10	30	31	30	19	191	52%
1972	17	28		4		18	31	31	30	22			181	64%
1973										8	20		28	4%
1974									5	31	30	23	89	17%
1975										2	30	11	43	1%
1976									13	29	30	31	103	20%
1977	31	25	22	12	6	30	31	31	18	16	30	16	268	67%
1978	22	28	11				22	25	30	31	30	31	230	50%
1979	29	22	3			4	8	31	30	31	22	15	195	49%
1980										1	30	25	56	0%
1981	28	9	22	13	13	13						24	122	18%
1982							2	31	30	31	16	4	114	44%
1983									2	27	10	7	46	14%
1984					7				12	31	24	24	98	23%
1985														0%
1986														0%
1987										18	18		36	8%
1988				21	27	1	6		27	30	29	31	172	52%
1989	29	28	31	22	29			8	29	31	29	31	267	56%
1990	23	16		2	11	13	31	31	5	15	29	22	198	50%
1991				13	17	23	12	13	30	24	26	31	189	62%
1992	26	14	4	5	2		13			1		3	68	10%
1993								19	30	31	27	28	135	37%
1994	26	8			5	13	31	31	30	31	30	23	228	66%
1995	9	19	4	7	27	28	31	19	30	22	29	29	254	77%
1996	23	25	17	18	22	13		31	24	26	8		207	63%
1997														0%
1998									26	31	30	31	118	27%
1999	21	19	10	21	27	10			21	31	30	31	221	51%
2000	31	29	31	23	21	23	28	31	30	31	30	31	339	87%
2001	29	15	31	30	31	30	4		21	27	28	29	275	67%
2002	31	22	29	6	10	7	31	31	30	31	30	29	287	68%
2003	31	28	27	30	19	18	31	31	30	31	30	29	335	89%
2004	30	25	24	29	9		27	15	21	31	29	26	266	62%
2005				9	28	12	5		15	31	30	27	157	47%
2006	19	25	27	30	9	30	31	31	22	28	26	25	303	85%
2007		16		6		14	28	21	30	31	30	28	204	61%
2008	28	17	2	2	31	25	6	27	19	31	28	25	241	66%

Table 13: Number of Days that Marsh Level Remained within ± 0.10m Limit from the Target Level for the Hemi Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	12	16	23						7	27	22	23	130	16%
1970	18	20	17	9	24	30	20	31	30	31	30	25	285	82%
1971	17	5	8	23		25	31	31	30	31	30	17	248	80%
1972	20	23		5		23	31	15	19	18			154	52%
1973										5	16		21	2%
1974									7	31	29	9	76	18%
1975										4	29	8	41	2%
1976									8	22	28	31	89	14%
1977	31	23	19	13	10	24	31	31	13	18	29	14	256	65%
1978	21	28	11				26	31	30	31	29	28	235	55%
1979	28	22	14			9	8	29	28	31	22	15	206	49%
1980										4	30	25	59	2%
1981	23	9	28	12	17	12		3			3	28	135	21%
1982	5						8	31	30	31	14	5	124	47%
1983									4	18	9	10	41	10%
1984					14				13	27	23	17	94	25%
1985	10	10											20	0%
1986														0%
1987										14	15		29	7%
1988			3	23		7	15	31	29	29	27	29	193	63%
1989	29	28	31	21	13		3	14	23	31	28	30	251	49%
1990	20	14		3	12	8	31	15	7	16	27	20	173	43%
1991				14	12	22	31	25	30	24	24	30	212	74%
1992	25	14	6	6	4	7	12			4		3	81	15%
1993								23	16	22	25	28	114	29%
1994	16	10			10	12	21	21	30	31	29	20	200	58%
1995	8	22	5	9	26	29	12	2	30	22	27	27	219	61%
1996	16	22	17	15	20	8		23	17	9	11		158	43%
1997												3	3	0%
1998									28	26			54	25%
1999	21	22	15	9	24	30	31	31	30	31	30	31	305	87%
2000	31	28	31	23	23	24	31	31	30	29	28	31	340	89%
2001	29	15	29	27	6	30	31	31	30	23	28	25	304	83%
2002	30	21	28	6	10	16	29	31	30	31	30	28	290	71%
2003	28	28	26	29	22	23	31	31	30	29	29	24	330	91%
2004	29	24	26	30	8	6	28	16	22	29	27	23	268	65%
2005				9	24	30	31	31	30	20	14	27	216	82%
2006	20	24	27	30	15	30	31	31	22	22	24	21	297	85%
2007		17		10		24	31	23	30	30	30	26	221	69%
2008	28	18	1	3	24	13	14	31	22	31	27	21	233	64%

Table 14: Number of Days that Marsh Level Remained within ± 0.15m Limit from the Target Level for the Hemi Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	20	21	24						11	31	23	26	156	20%
1970	25	22	25	15	30	30	29	31	30	31	30	28	326	92%
1971	23	7	13	25	8	28	31	31	30	31	30	21	278	86%
1972	22	29	4	9		28	31	25	30	21			199	67%
1973										10	19	1	30	5%
1974									9	31	30	22	92	19%
1975										7	30	12	49	3%
1976									21	24	30	31	106	21%
1977	31	24	25	16	12	28	31	31	17	19	29	18	281	72%
1978	26	28	12			1	31	31	30	31	30	31	251	58%
1979	29	22	14	1		13	9	31	30	31	22	20	222	54%
1980										13	30	26	69	6%
1981	28	10	31	13	25	13		6		3	15	31	175	28%
1982	9	4					12	31	30	31	17	9	143	49%
1983	14		12						6	26	12	14	84	15%
1984					16			2	15	31	24	25	113	30%
1985	12	11											23	0%
1986														0%
1987										18	18		36	8%
1988			19	30	5	28	26	31	30	30	29	31	259	84%
1989	29	28	31	23	27		5	20	29	31	28	31	282	63%
1990	26	16	6	8	13	11	31	22	10	20	29	23	215	54%
1991		2		17	16	24	31	28	30	24	28	31	231	79%
1992	27	15	9	13	9	17	13		1	8		10	122	29%
1993								26	22	30	28	31	137	36%
1994	27	12			12	12	24	25	30	31	30	25	228	63%
1995	9	23	12	10	29	30	20	6	30	23	28	28	248	69%
1996	24	25	23	20	23	11		29	20	15	22	3	215	55%
1997											13	13	26	0%
1998									30	31	24		85	29%
1999	21	23	26	15	28	30	31	31	30	31	30	31	327	92%
2000	31	29	31	24	25	27	31	31	30	31	29	31	350	93%
2001	29	17	31	30	20	30	31	31	30	25	28	30	332	92%
2002	31	24	31	10	11	19	31	31	30	31	30	28	307	76%
2003	31	28	27	30	28	25	31	31	30	29	30	28	348	95%
2004	31	26	27	30	10	12	31	19	27	31	28	28	300	75%
2005		4		13	27	30	31	31	30	31	29	28	254	90%
2006	22	25	28	30	20	30	31	31	23	27	27	25	319	90%
2007	8	19	7	15	8	26	31	29	30	31	30	26	260	79%
2008	28	19	2	5	31	23	16	31	23	31	28	26	263	75%

Table 15: Number of Days that Marsh Level Remained within ± 0.20m Limit from the Target Level for the Hemi Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	23	24	26	1					14	31	26	29	174	21%
1970	27	26	27	19	31	30	31	31	30	31	30	31	344	95%
1971	27	13	22	29	14	29	31	31	30	31	30	28	315	91%
1972	26	29	9	11		30	31	31	30	22			219	72%
1973										14	22	14	50	7%
1974									12	31	30	28	101	20%
1975								4		9	30	25	68	6%
1976	12								30	27	30	31	130	27%
1977	31	26	26	17	14	30	31	31	24	22	30	20	302	79%
1978	29	28	13			6	31	31	30	31	30	31	260	60%
1979	30	24	17	3	3	15	11	31	30	31	23	22	240	58%
1980		14								22	30	29	95	10%
1981	31	17	31	14	31	13		8		8	21	31	205	35%
1982	12	8					18	31	30	31	21	20	171	51%
1983	21	5	26						8	29	17	16	122	17%
1984	9				20			9	20	31	26	30	145	37%
1985	17	20											37	0%
1986														0%
1987										26	19	2	47	12%
1988	11	8	31	30	20	28	31	31	30	31	30	31	312	94%
1989	30	28	31	27	29		8	23	30	31	30	31	298	69%
1990	27	18	11	13	14	15	31	31	11	21	30	25	247	64%
1991		9	2	18	21	28	31	31	30	24	30	31	255	86%
1992	30	17	18	19	13	25	13		5	15		17	172	42%
1993								28	29	31	30	31	149	41%
1994	27	14	3		14	13	29	27	30	31	30	27	245	67%
1995	17	25	15	16	31	30	31	21	30	25	29	30	300	86%
1996	28	27	24	25	25	14	5	31	25	21	26	13	264	68%
1997	4										30	23	57	0%
1998								7	30	31	30	31	129	32%
1999	22	25	29	21	31	30	31	31	30	31	30	31	342	96%
2000	31	29	31	25	26	29	31	31	30	31	30	31	355	95%
2001	30	22	31	30	31	30	31	31	30	31	28	30	355	100%
2002	31	26	31	14	15	21	31	31	30	31	30	29	320	81%
2003	31	28	30	30	31	27	31	31	30	31	30	31	361	99%
2004	31	26	29	30	14	17	31	20	29	31	30	30	318	80%
2005	3	5	13	16	29	30	31	31	30	31	30	28	277	93%
2006	29	28	29	30	21	30	31	31	25	29	29	28	340	92%
2007	14	20	15	21	12	29	31	31	30	31	30	30	294	86%
2008	29	22	2	7	31	25	18	31	24	31	29	28	277	78%

Table 16: Number of Days that Marsh Level Remained within ± 0.10m Limit from the Target Level for the Overgrown Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	7	24	26	9	8				18	27	22	23	164	29%
1970	26	24	27	21	27	30	31	31	30	31	30	25	333	94%
1971	27	11	24	30	31	30	31	31	29	29	30	17	320	99%
1972	25	29	14	14	5	30	31	30	4	3			185	55%
1973											10		10	0%
1974								11	13	27	19	15	85	24%
1975							11	24			19	8	62	16%
1976	20							25	24	16	29	31	145	30%
1977	31	25	25	22	19	29	31	31	15	18	29	14	289	77%
1978	30	28	12			12	31	31	30	31	29	28	262	63%
1979	31	22	18	3	7	17	18	31	25	18	22	15	227	56%
1980	5	19	9				4			10	30	25	102	7%
1981	28	18	31	19	22	13	12	22			3	28	196	41%
1982	13	10	5		14	19	31	31	30	30	13	5	201	72%
1983	24	12	26					6	9	10	7	10	104	12%
1984	26	1			21		20	18	18	7	19	17	147	39%
1985	19	12											31	0%
1986														0%
1987								1		12	13		26	6%
1988	17	14	31	30	31	29	31	31	28	29	26	31	328	98%
1989	29	28	31	27	29		18	29	27	31	28	30	307	75%
1990	26	17	14	17	15	19	31	28	12	17	27	20	243	65%
1991	5	14	23	18	17	14	31	29	30	24	24	30	259	76%
1992	28	18	17	17	13	27	18	18	3	6		3	168	48%
1993							7	31	21	22	25	28	134	38%
1994	26	13	9	5	19	12	31	27	30	25	29	20	246	70%
1995	17	28	19	11	25	29	29	23	30	23	26	27	287	79%
1996	25	24	24	25	21	9	29	31	16		10		214	61%
1997	5											3	8	0%
1998							10	30	30	31	30	31	162	47%
1999	22	26	28	21	31	30	31	31	25	31	30	31	337	93%
2000	31	28	31	22	27	27	31	31	30	30	28	31	347	93%
2001	29	19	31	30	31	30	31	31	30	24	28	26	340	97%
2002	31	24	31	19	18	24	30	31	30	31	30	28	327	86%
2003	30	28	27	30	29	26	31	31	30	29	29	24	344	96%
2004	31	25	28	30	19	18	31	22	27	29	27	23	310	82%
2005	8	5	23	21	31	30	31	31	30	31	28	27	296	96%
2006	28	24	28	30	21	30	31	31	23	22	25	21	314	88%
2007	17	19	19	18	19	28	31	30	30	31	30	26	298	87%
2008	28	20	2	13	31	21	22	31	24	31	26	21	270	81%

Table 17: Number of Days that Marsh Level Remained within ± 0.15m Limit from the Target Level for the Overgrown Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	8	25	28	12	8		1	4	20	31	24	26	187	36%
1970	27	27	28	22	31	30	31	31	30	31	30	28	346	96%
1971	28	17	24	30	31	30	31	31	30	31	30	21	334	100%
1972	29	29	22	15	11	30	31	31	21	6			225	68%
1973									5	9	18	1	33	7%
1974								26	27	31	30	23	137	39%
1975					2	15	20	24		3	29	12	105	30%
1976	21	2					15	31	30	17	30	31	177	43%
1977	31	27	26	22	21	30	31	31	24	20	29	18	310	84%
1978	31	28	13			26	31	31	30	31	30	31	282	70%
1979	31	23	21	5	17	22	22	31	30	27	22	20	271	72%
1980	10	23	16				27	7		20	30	26	159	25%
1981	30	21	31	26	30	13	18	24	1	1	15	31	241	53%
1982	19	16	10		31	28	31	31	30	31	16	9	252	85%
1983	30	25	26			2		13	20	22	12	14	164	27%
1984	31	1	7		24		31	24	26	23	23	26	216	60%
1985	23	21						1					45	0%
1986														0%
1987								8		23	18		49	14%
1988	20	26	31	30	31	30	31	31	30	30	29	31	350	100%
1989	29	28	31	30	29	4	18	31	30	31	29	31	321	81%
1990	28	19	22	27	20	25	31	31	12	21	29	23	288	78%
1991	8	20	29	18	27	19	31	31	30	24	27	31	295	84%
1992	31	20	23	20	19	30	21	24	5	12		10	215	61%
1993						3	16	31	25	31	28	31	165	50%
1994	27	18	17	16	23	14	31	31	30	28	30	25	290	81%
1995	23	28	21	19	31	30	31	26	30	24	28	28	319	89%
1996	27	27	25	28	27	11	31	31	22	11	21	3	264	75%
1997	10										10	12	32	0%
1998							23	31	30	31	30	31	176	54%
1999	23	27	31	22	31	30	31	31	30	31	30	31	348	96%
2000	31	29	31	26	28	29	31	31	30	31	29	31	357	96%
2001	29	20	31	30	31	30	31	31	30	27	28	30	348	98%
2002	31	26	31	24	20	26	31	31	30	31	30	28	339	90%
2003	31	28	29	30	31	27	31	31	30	29	30	28	355	98%
2004	31	27	28	30	21	21	31	25	29	31	28	28	330	88%
2005	13	13	28	28	31	30	31	31	30	31	30	28	324	99%
2006	29	27	30	30	22	30	31	31	25	27	27	25	334	92%
2007	24	23	21	22	21	30	31	31	30	31	30	27	321	92%
2008	29	21	6	19	31	26	23	31	25	31	28	26	296	87%

Table 18: Number of Days that Marsh Level Remained within ± 0.20m Limit from the Target Level for the Overgrown Marsh Phase

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%Time
1969	12	25	29	19	9		9	10	22	31	26	29	221	47%
1970	29	28	30	25	31	30	31	31	30	31	30	31	357	98%
1971	30	21	29	30	31	30	31	31	30	31	30	28	352	100%
1972	30	29	25	15	22	30	31	31	28	10			251	78%
1973								1	14	15	21	14	65	14%
1974							2	31	30	31	30	28	152	44%
1975	5	1			16	23	31	28		16	30	24	174	53%
1976	24	3				1	22	31	30	23	30	31	195	50%
1977	31	28	30	22	23	30	31	31	26	23	30	20	325	87%
1978	31	28	13		11	30	31	31	30	31	30	31	297	77%
1979	31	25	23	10	24	28	25	31	30	31	23	22	303	84%
1980	16	28	16		12	1	31	23	3	24	30	29	213	44%
1981	31	23	31	30	31	17	18	29	6	11	21	31	279	66%
1982	23	22	11		31	30	31	31	30	31	21	20	281	86%
1983	31	27	26	6		9	9	20	30	29	17	16	220	48%
1984	31	12	14		24	2	31	27	30	31	25	30	257	68%
1985	25	21					3	13	3				65	9%
1986														0%
1987							8	25	1	28	19	2	83	29%
1988	27	29	31	30	31	30	31	31	30	31	30	31	362	100%
1989	30	28	31	30	29	12	20	31	30	31	30	31	333	86%
1990	28	20	26	30	25	27	31	31	13	22	30	25	308	84%
1991	8	24	31	18	30	23	31	31	30	24	30	31	311	87%
1992	31	22	29	22	22	30	24	29	11	22		17	259	75%
1993			1			6	31	31	28	31	30	31	189	59%
1994	30	19	27	23	29	25	31	31	30	31	30	27	333	93%
1995	27	28	23	26	31	30	31	28	30	25	29	30	338	94%
1996	30	28	26	30	29	17	31	31	25	19	26	13	305	85%
1997	11									5	26	23	65	2%
1998						4	31	31	30	31	30	31	188	59%
1999	24	28	31	26	31	30	31	31	30	31	30	31	354	98%
2000	31	29	31	28	29	30	31	31	30	31	30	31	362	98%
2001	30	22	31	30	31	30	31	31	30	31	28	30	355	100%
2002	31	28	31	28	22	28	31	31	30	31	30	29	350	94%
2003	31	28	31	30	31	29	31	31	30	31	30	31	364	100%
2004	31	27	29	30	26	25	31	28	30	31	30	30	348	94%
2005	21	19	31	30	31	30	31	31	30	31	30	28	343	100%
2006	30	28	31	30	24	30	31	31	26	30	29	28	348	94%
2007	26	26	26	27	25	30	31	31	30	31	30	30	343	96%
2008	29	24	12	24	31	27	27	31	26	31	28	28	318	92%

Table 19: Controlled Water Balance Components for Open Water Marsh in Different Hydrologic Conditions

Hydrologic Condition	Year	Water Released from the Marsh through Gate		Water Taken from the Lake through Gate		Water Pumped out from the Marsh		Water Pumped Into the Marsh	
		Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days
Dry	2005	15,124,818	121	641,855	15	3,534,800	40	353,480	4
Dry	1999	8,253,841	82	156,071	5	3,181,320	36	530,220	6
Dry	1982	17,049,137	209	533,449	4	2,474,360	28	176,740	2
Average	2007	18,454,390	193	18,290	1	3,799,910	43	0	0
Average	2001	21,749,503	104	0	0	1,502,290	17	176,740	2
Average	1973	12,734,649	268	0	0	795,330	9	0	0
Wet	1986	8,521,811	241	0	0	0	0	0	0
Wet	1981	18,094,137	220	0	0	9,897,440	112	0	0
Wet	1969	22,852,954	294	0	0	2,562,730	29	0	0

Table 20: Controlled Water Balance Components for Open Water 2 Marsh in Different Hydrologic Conditions

Hydrologic Condition	Year	Water Released from the Marsh through Gate		Water Taken from the Lake through Gate		Water Pumped out from the Marsh		Water Pumped Into the Marsh	
		Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days
Dry	2005	15,704,103	118	944,358	22	2,562,730	29	883,700	10
Dry	1999	8,888,674	80	720,297	12	2,562,730	29	1,148,810	13
Dry	1982	17,502,212	208	329,652	5	1,590,660	18	176,740	2
Average	2007	19,464,105	188	0	0	1,767,400	20	0	0
Average	2001	22,713,458	97	355,248	9	176,740	2	706,960	8
Average	1973	12,734,638	268	0	0	795,330	9	0	0
Wet	1986	8,521,811	241	0	0	0	0	0	0
Wet	1981	21,353,302	255	0	0	6,009,160	68	0	0
Wet	1969	23,857,541	286	0	0	1,502,290	17	0	0

Table 21: Controlled Water Balance Components for Hemi Marsh in Different Hydrologic Condition

Hydrologic Condition	Year	Water Released from the Marsh through Gate		Water Taken from the Lake through Gate		Water Pumped out from the Marsh		Water Pumped Into the Marsh	
		Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days
Dry	2005	16,828,720	125	247,160	16	1,237,180	14	1,944,140	22
Dry	1999	9,889,376	75	14,162	4	530,220	6	2,739,470	31
Dry	1982	18,225,330	199	131,638	5	972,070	11	353,480	4
Average	2007	21,265,487	166	0	0	706,960	8	1,060,440	12
Average	2001	22,814,772	65	0	0	0	0	1,944,140	22
Average	1973	13,165,426	273	0	0	353,480	4	0	0
Wet	1986	8,521,811	241	0	0	0	0	0	0
Wet	1981	24,062,147	254	85,258	1	3,358,060	38	0	0
Wet	1969	23,964,368	253	0	0	883,700	10	0	0

Table 22: Controlled Water Balance Components for Overgrown Marsh in Different Hydrologic Condition

Hydrologic Condition	Year	Water Released from the Marsh through Gate		Water Taken from the Lake through Gate		Water Pumped out from the Marsh		Water Pumped Into the Marsh	
		Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days	Volume (m^3)	No. of days
Dry	2005	17,735,803	106	0	0	0	0	1,944,140	22
Dry	1999	10,109,845	47	0	0	0	0	2,474,360	28
Dry	1982	18,991,082	186	6,868	1	397,899	6	706,960	8
Average	2007	21,987,766	114	0	0	0	0	1,237,180	14
Average	2001	22,954,758	54	0	0	0	0	2,385,990	27
Average	1973	13,515,575	279	0	0	0	0	0	0
Wet	1986	8,521,811	241	0	0	0	0	0	0
Wet	1981	26,606,766	234	0	0	0	0	0	0
Wet	1969	24,728,586	237	0	0	0	0	0	0

2012

Big Creek Watershed Plan
Water Quality Study

Essex Region Conservation Authority

Town of Amherstburg

11/7/2012

Study Methods

The surface water quality monitoring study included two main components. Firstly, historical and long term water quality data in the Big Creek watershed was analyzed to determine if any long term significant trends exist in the watershed. Secondly, the assessment of current (2008-2009) water quality conditions was undertaken by conducting a comprehensive surface water monitoring program during 2008 and 2009. Data for various parameters were analyzed in both components of the study to evaluate long term and current water quality. The study also included a quantitative estimation of loadings of particular pollutants from different catchments within the watershed.

Historic Long-term Water Quality

For the analysis of historical, long term water quality conditions, data from a provincial surface water monitoring program and from a provincial rural beaches strategy program were analyzed.

The Provincial Water Quality Monitoring Network (PWQMN) is a partnership program between the Ontario Ministry of the Environment (MOE), Conservation Authorities, several municipalities and an Ontario Park. Through the PWQMN, two surface water quality sites were monitored in the Big Creek watershed. The first site was located at County Road 20, south of Amherstburg and was monitored from 1964 to 1970. The second site was located at Creek Road (old Malden Township), south of Amherstburg and monitored from1982 to 1996. In 1997, this site was removed from the PWQMN network.

Samples were analyzed for regular chemistry, nutrient and metals listed in Table 4.1.

Table 4.1: List of Water Quality Parameters Analyzed in the PWQMN Samples

Parameter Category	Water Quality Parameters
Physical	Temperature (^{0}C) and turbidity (NTU)
Chemical	pH, Alkalinity (mg/L), and conductivity (mS/cm)
Nutrients	Ammonia, Nitrate+nitrite, phosphate, total phosphorus, Total Kjeldahl Nitrogen (TKN)
Solids	Total suspended solids (TSS) and total dissolved solids (TDS)
Metals	Aluminum, barium, beryllium, cadmium, chromium, copper, iron, manganese, molybdenum, nickel, lead, strontium, titanium, vanadium and zinc (all μg/L)
Major ions	Calcium, magnesium, sodium, potassium, hardness and chloride
Pesticides	Phenoxy Acid and Triazine herbicides, and Organophosphorus insecticides

In 1989-1990, the Ontario Ministry of the Environment (MOE) and the Essex Region Conservation Authority (ERCA) conducted a surface water quality study for the Big Creek watershed. This study is called the Essex Conservation Rural Beaches Program (ECRB), and is the only comprehensive surface water quality study conducted in the Big Creek watershed in the past. This program was funded by MOE as a part of the Provincial Rural Beaches Strategy Program initiated in 1984. This program was a result of the conclusion from studies conducted by the MOE on frequent beach postings that occurred since the 1970s throughout Southern Ontario. The program mainly focused on livestock waste management practices and faulty septic systems that may contribute fecal bacteria to surface water systems. In 1989, ERCA became one of the Conservation Authorities (CAs) to participate in the strategy program in order to address the issues of frequent beach postings at Holiday Beach, due to high bacteria levels. ERCA implemented this program in two phases; the first phase included water quality analysis and livestock operation assessments, while the second phase focused mainly on source identification and development of a Clean Up Rural Beaches Plan (CURB). Figure 4.1 shows the location of water quality monitoring sites that were monitored during the Phase I and Phase II Study periods. Phase I and Phase II included 32 stations and 47 stations, respectively, with varying sampling frequency.

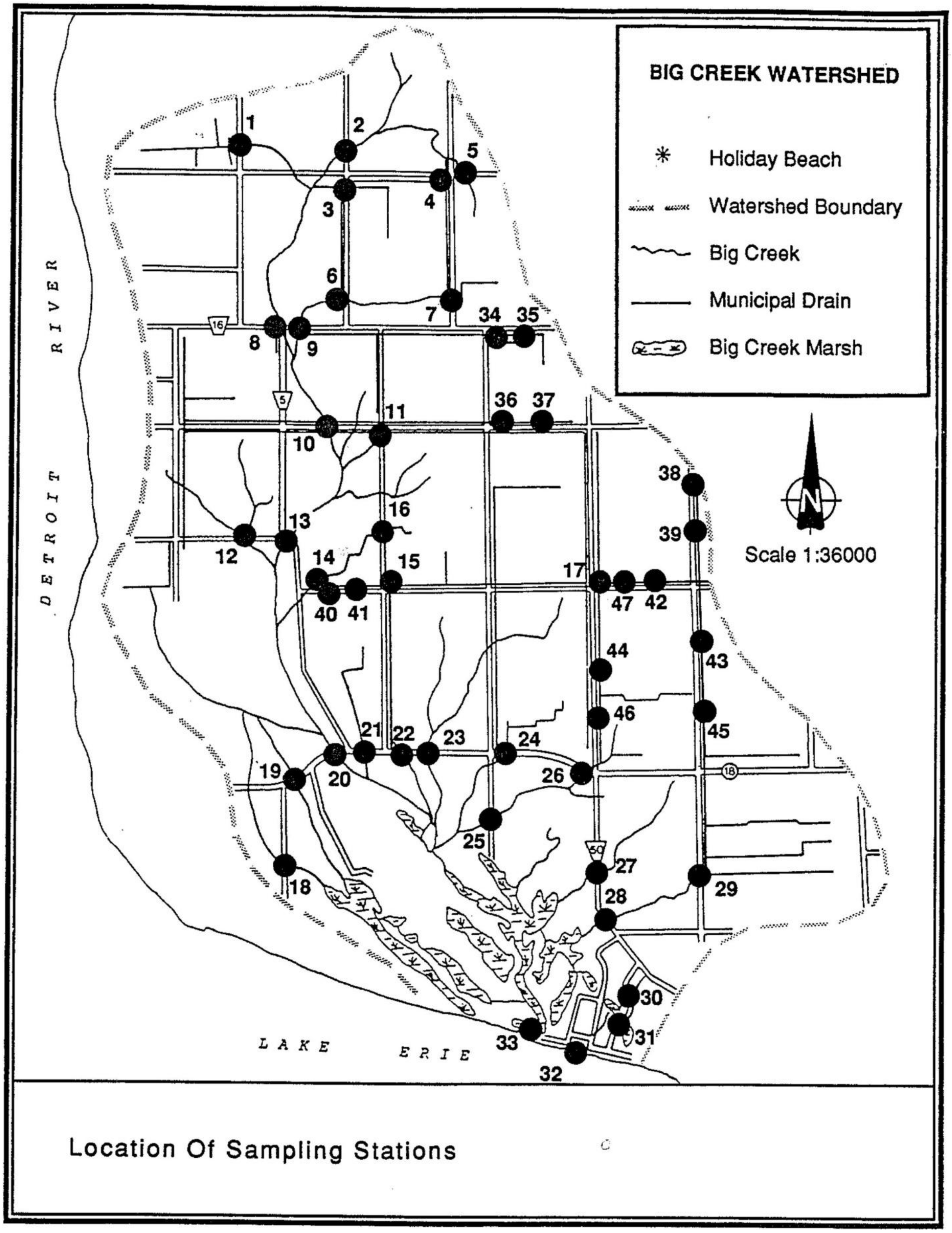


Figure 1 Locations of Sampling Stations

Table 4.2: Summary of the Surface Water Monitoring Study of the ECRB Program (1989-1990)

Study Period	Number of Sampling Stations	Frequency of Sampling	Chemical Parameters	Microbial Parameters
Phase-I (July 1989 to February 1990)	32	1 to 5[1]	Total Phosphorus (TP), Dissolved Phosphorus (DP), Total Kjeldahl Nitrogen (TKN), Nitrate, Nitrite, Chloride, and pH	Fecal Coliform (FC), E.coli, Fecal Streptococci (FC) and Pseudomonas aeruginosa (Pseudomonas)
Phase-II (October 1990 to November 1990)	47	5 to 10[1]	Total Phosphorus (TP), Dissolved Phosphorus (DP), Total Kjeldahl Nitrogen (TKN), Nitrate, Nitrite, Chloride, and pH	Fecal Coliform (FC), E.coli, Fecal Streptococci (FC) and Pseudomonas aeruginosa (Pseudomonas)

[1]Frequency of a particular station depended on contaminant concentrations in past sampling runs

Current Water Quality

For the assessment of current water quality conditions, an initial land use survey of the Big Creek watershed was initiated using aerial maps and field visits to examine visual water quality and identify potential sampling locations. Historical water quality monitoring locations, as well as ERCA's on-going surface water monitoring sites in the watershed, were considered. Selected sites were based on the land use pattern and the drainage pattern (using Arc Hydro and DEM) in the Big Creek watershed. Accessibility of the sampling sites was also a factor in deciding the location of sampling sites. Samples were taken along tributary streams (6 sites: BC-1, BC-2, BC-3, BC-4, BC-5 and BC-N), at the marsh inlet and outlet (2 sites: Marsh-I, Marsh-O) and Lake Erie nearshore upstream and downstream (2 sites: Lake-U, Lake-D) of the marsh outlet. Samples were taken during regular and wet (rain event) weather. Figure 4.2 shows the sampling site locations of the assessment of current water quality conditions.

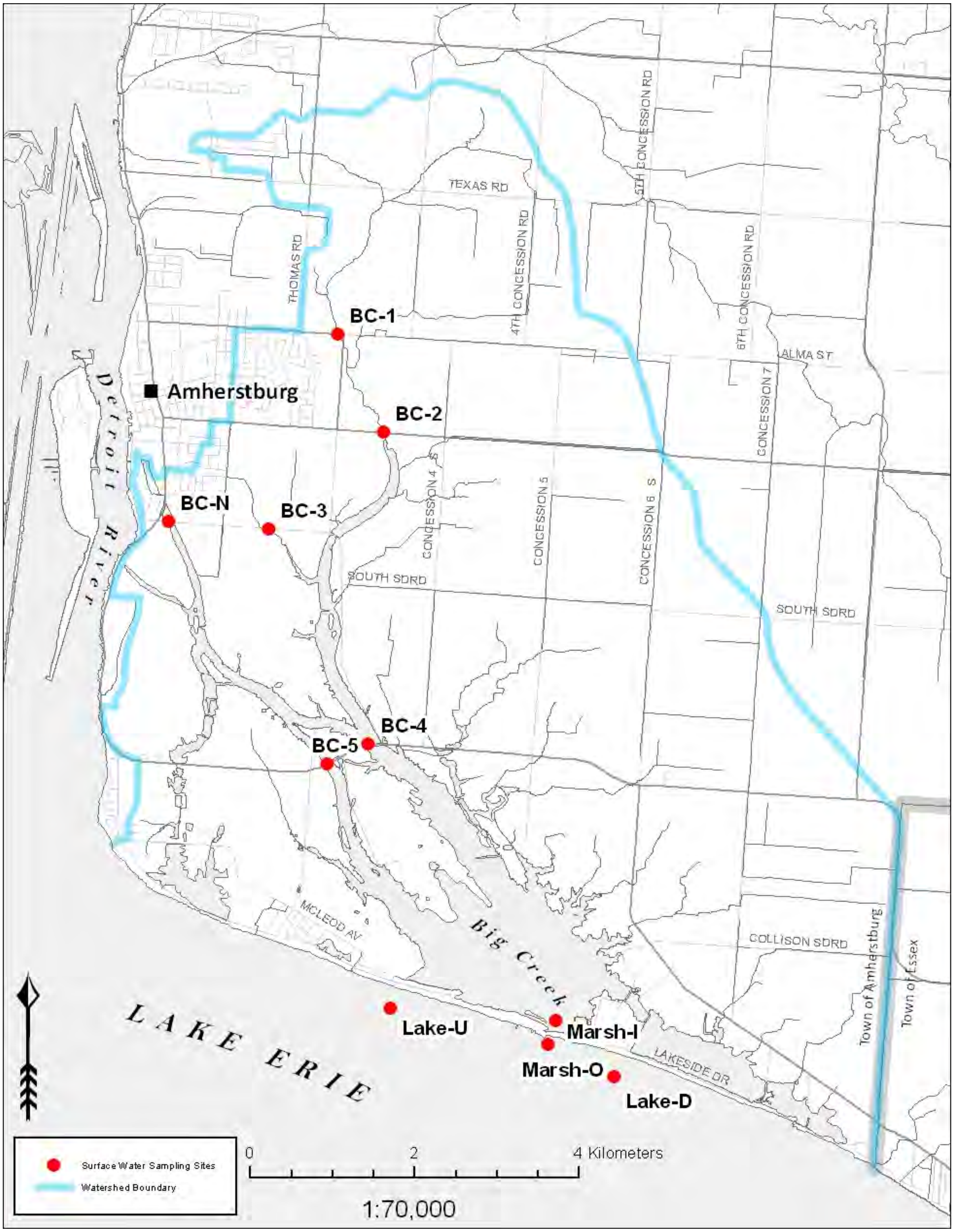


Figure 2 Surface Water Sampling Sites in the Big Creek Watershed

Water Quality Parameters Analyzed

The parameters analyzed in the water samples at each site are indicators of the current water quality conditions. The assessment of current water quality focused on general physical and chemical parameters, nutrients and Escherichia coli (E. coli) from June 2008 to November 2009. Metals, pesticides and benthics (sediment bugs) were sampled a limited number of times during the study period.

The quality of stream biota provides a direct assessment of stream conditions as it reflects the influence of human activity in the surrounding watershed. Benthic macroinvertebrates monitoring is key to understanding the health of biological assemblages in a stream. If a stream's benthic invertebrate population is degraded, it is safe to conclude that the stream will not support healthy fish populations. Benthic macroinvertebrates may include mayfly larvae, stonefly larvae, caddisfly larvae, worms, beetles, snails, dragonfly larvae, and many others. These organisms are long-term inhabitants of streams, relatively immobile, easy to collect, and represent an assemblage that responds predictably to impacts of human origin. Benthic macroinvertebrates monitoring can provide insight into the biological integrity of a stream. Hence, detailed benthic macroinvertebrates monitoring was conducted at eight of the water quality sampling sites in the Big Creek watershed (excluding lake sites).

Fecal contamination of surface water systems is a widespread problem across the world. It is also recognized as a significant problem in many areas across Canada (Edge and Schaefer, 2006). Fecal pollution can be attributed to diverse sources such as municipal sewage treatment effluents, faulty private septic systems, livestock manure application, and wildlife droppings. In general, total coliform, fecal coliforms, E. coli, and enterococci are used as bacterial indicators in water quality and health risks assessments (Meays et al., 2004). These bacteria are not pathogenic (disease-causing) by themselves, but they are normally prevalent in the intestines and feces of warm-blooded mammals, including wildlife, livestock, and humans. The presence of E. coli or fecal coliform bacteria in the aquatic ecosystem indicates that fecal contamination has occurred.

Table 1 Summary of the Current Big Creek Surface Water Monitoring Study (2008-2009)

Study Period	Sampling Sites	Frequency of Sampling	Parameters
June 2008 to November 2009	BC-1, BC-2, BC-3, BC-4, BC-5, BC-N, Marsh-I, Marsh-O, Lake-U, Lake-D	Twice a month for regular weather and 5/12 wet weather events	General physical-chemical: pH, dissolved oxygen (DO), temperature, chloride, total suspended solids (TSS). Nutrients: total phosphorus (TP), total nitrate. Bacteria: E. coli. Flow measurements were made during wet weather events.
		3 times during the study period (every 5 months)	Metals: arsenic, cadmium, chromium, copper, iron, lead and zinc. Pesticides: atrazine, 2,4-D, metolachlor and glyphosate
Spring 2009	BC-1, BC-2, BC-3, BC-4, BC-5, BC-N, Marsh-I, Marsh-O	In spring 2009	Benthic invertebrates

Sampling for Physical-Chemical Parameters, Bacteria, Metals and Pesticides

In order to ensure consistent water quality data, the sampling protocols used in the PWQMN program and the ERCA's region-wide Surface Water Monitoring Program were used in this study for determining physical-chemical parameters, bacteria, metals and pesticides. Samples were collected at each site using clean polyethylene bottles. Sterile 500 ml polyethylene bottles were used for bacterial analysis. All metal samples were preserved with nitric acid (to achieve a pH of below 4). Samples for metals and pesticides were taken using one litre, solvent washed amber glass bottles. The Standard Methods, 1999, recommended by the American Water Works Association (AWWA) and the Water Environment Federation (WEF) for preservation and storage of samples for specific parameters were followed. The samples were taken in ice coolers to a certified lab (Caducean Laboratory, Windsor) within 12 hours of sample collection. A hand held YSI Sonde (model 600QS) was used to measure field pH, dissolved oxygen, water temperature and conductivity of surface water.

Sampling for Benthic Invertebrates

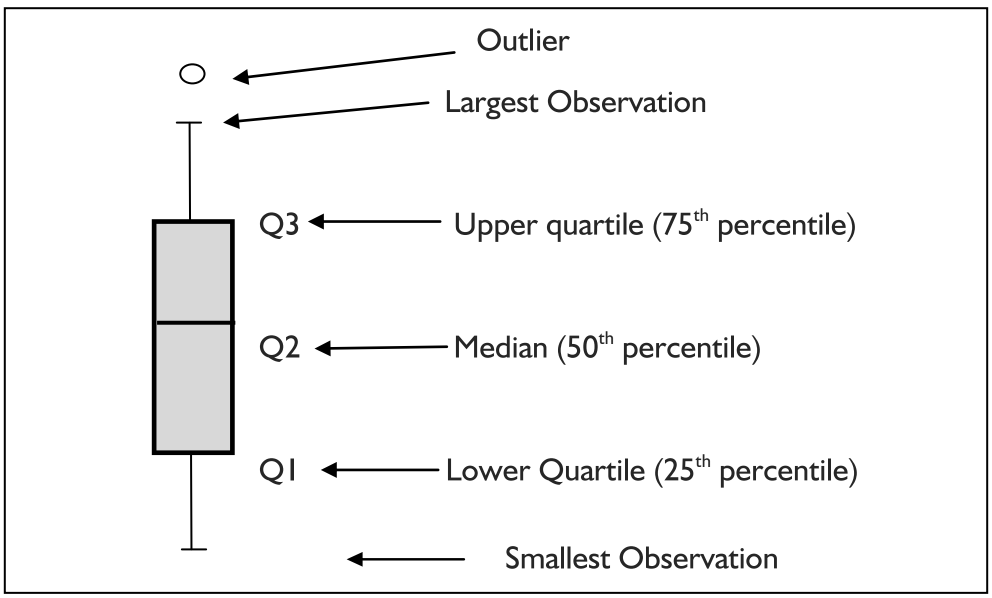
Benthic invertebrates sampling was conducted over a one week period, three times during the study period. Three replicate sediment samples were collected using kick and net method prescribed by the Ontario Benthic Biomonitoring Network (OBBN). Samples were rinsed using a sieve of 500 µM mesh size and the organisms retained in the sieve were counted and identified with their common names at the site. Nearly all insects collected during study were keyed down to species level. A selected number of identified and unidentified organisms were preserved in 80% ethanol for further identification using a microscope in the lab. However, some macroinvertebrates, such as roundworms and leeches, were keyed only to phylum, order, class, or sub-class level. These data were finally used to calculate the benthic index of biological integrity (B-IBI) which is explained in more detail in the following section.

Statistical Analysis

Water quality results observed during 2008 and 2009 were occasionally below the reporting limits of the analytical methods used by Caducean Laboratory in Windsor. In those cases, the results were reported by the laboratory as < MDL (i.e. less than method detection limit). For example, the MDL for total phosphorus is 0.01 mg/L (or 10 µg/L). In such instances, a value of one-half of the MDL was substituted for the result (Bhattacharya and Johnson, 1977).

Initially, the data set for selected parameters was explored on box-whisker plots using SigmaPlot® to characterize the data and examine the distribution of the data to aid in the subsequent analyses. Boxplot graphically depicts groups of numerical data through five-number summaries; smallest observation, lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation as shown in Figure 4.3. Any data not included in these groups is usually plotted as an outlier with a dot or a star.

Figure 4.3 Schematic of a Typical Boxplot with Whiskers from Minimum to Maximum



In addition, other statistical techniques such as summary statistical measures and formal statistical methods for normal distribution of the data were employed. Basic descriptive statistics were tabulated using Microsoft Excel 97, the normality test and the Kruskal-Wallis analysis of ranks was performed using SigmaPlot version 11.0. Water quality data sets were also assessed to find any seasonal trends associated with a particular parameter.

The data set for each parameter was compared with respective water quality objectives, guidelines and other relevant criteria that were established for the protection of aquatic life. These guidelines are summarized in Table 4.4. The level of exceedance was then determined by calculating the percentage of samples not meeting objectives, guidelines or criteria for the data collected during 2008 and 2009.

Pollutant Loading Estimation

The Water Quantity Study Report, which is a part of the Big Creek Watershed Management Plan, presents the results of sediment and nutrient loading estimations using the Agricultural Non Point Source Pollution (AGNPS) Model. Please refer to the Water Quantity Study Report for more details on methodology, results and limitations of pollutant loading estimation study for the Big Creek watershed.

Determining Sources of Bacteria

Bacterial source tracking (BST), or microbial source tracking (MST), is an emerging field in the determination of sources of fecal bacteria (wildlife, humans, and domestic livestock) from environmental samples. The MST methodologies, in general, compare the similarities of microorganisms collected from aquatic ecosystem to microorganisms collected from nearby fecal pollution sources to determine the likely source of fecal contamination. This field is rapidly growing in terms of field studies and the accuracy and reliability of MST techniques (Edge and Schaefer, 2006). To date, various MST methods have been developed which could be broadly classified into three major groups; molecular, biochemical, and chemical. These methods can also be classified as library-dependant or library-independent methods. In United States, MST studies have been using “genomic fingerprints” from bacterial strains isolated from a water sample matching with those isolated from different hosts (e.g. humans, domesticated animals, wildlife). It is very critical to understand that there are no standardized methods adopted for source tracking, and moreover, there are pros and cons of various methods currently available in terms of cost and time requirements, reproducibility and accuracy of results. More details on these methods including limitations, and current state of the science can be found in Environment Canada’s Scientific Assessment Report (2006) as well as various other peer reviewed scientific articles (Meays et al., 2004, Griffith et al, 2003, USEPA, 2005).

For the purpose of the current study, a screening level source tracking method was used to determine the potential sources of fecal contamination in the Big Creek watershed. This method utilizes ratios of fecal coliform (FC) to fecal streptococci (FS) to assess the general source of non-point fecal pollution. This method was very popular and had been widely used in the past for source tracking purposes (Geldreich, 1976), however there are some limitations identified for its use in agricultural settings (Howell et al, 1996). With all the limitations associated with this method, it is important to note that FC/FS ratios can be successfully employed as a screening level method for microbial source tracking. A ratio greater than 4.0 indicates human pollution, while a ratio less than or equal to 0.7 indicates non-human pollution (Geldreich and Kenner, 1969).

Based on E. coli levels observed during 2008 and 2009 at various sampling sites in the Big Creek watershed, an intensive sampling was conducted during fall 2009 at all the sites. In addition to E. coli, samples were analyzed for fecal coliform, total coliform, fecal streptococci. The FC/FS ratios for each sample were computed and compared with ranges of FC/FS ratios associated with different types of fecal sources as described by Geldreich and Kenner (1969).

Evaluation Criteria

Physical, Chemical and Bacterial Parameters

The water quality parameter data was evaluated using benchmarks for the protection of aquatic life and ecosystem health. These benchmarks are the Provincial Water Quality Objectives (PWQO) published by the Ministry of Environment (MOE), the Canadian Environmental Quality Guidelines (CEQG) published by the Canadian Council of Ministries of the Environment (CCME), and a recreational water use standard for bacteria. Table 4.4 provides the benchmarks used to evaluate the water quality data.

Table 4.4: Water Quality Parameters and Corresponding Benchmarks

Parameters	Benchmarks	Sources
pH	6.5 – 8.5	PWQO
Temperature	24°C	Long Point Region Conservation Authority 2005 Technical Report
Dissolved Oxygen	4 mg/L	PWQO
Total Phosphorus (TP)	0.03 mg/L (30 μg/L)	PWQO
Total Nitrate	2.93 mg/L	CCME
Chloride	210 mg/L	Environment Canada
Total Suspended Solids (TSS)	25 mg/L	CCME and PWQO
Escherichia coli (E. coli)	100 CFU/100mL	PWQO
Atrazine	1.8 μg/L	PWQO
Metolachlor	3 μg/L	PWQO
2,4-D	0.2 μg/L	PWQO
Glyphosate	65 μg/L	CCME
Arsenic	5 μg/L	PWQO
Cadmium	0.2 μg/L	PWQO
Chromium (hexavalent)	1 μg/L	PWQO
Copper	5 μg/L	PWQO
Iron	300 μg/L	PWQO
Lead	5 μg/L	PWQO
Zinc	20 μg/L	PWQO

Notes: PWQO: Provincial Water Quality Objectives for the protection of aquatic life and ecosystems. CCME: Canadian Council of Ministers for the Environment (Canadian environmental quality guidelines for the protection of aquatic life)

Benthic Invertebrates

Benthic invertebrate data from the current water quality (2008-2009) was analyzed using the Benthic Index of Biotic Integrity (B-IBI). The B-IBI is a multimetric indices approach which utilizes different biological characteristics to numerically illustrate associations between human impacts and biological attributes (Kelmm et al., 1990). Ten summary metrics, described in Table 4.5, were used to calculate the B-IBI value of each site. All organisms found at each sampling site were identified and counted. Each metric was then tabulated using these data. Next, each metric was assigned a score of 1, 3, or 5, representing severely degraded, somewhat degraded, and undisturbed sites, respectively. The individual metric scores were then summed resulting in a total B-IBI score for each site, which could range from 10 to 50. This total score corresponds to the qualitative coding system for stream condition listed in Table 4.6.

Table 4.5: The Ten Metrics and Corresponding Scoring Criteria used in the Index of Biotic Integrity (B-IBI) Scoring

Metrics	Scoring Criteria
Total taxa richness	Total number of unique taxa identified in each replicate. The three replicates are then averaged for this metric.
Ephemeroptera (mayfly) taxa richness	Total number of unique mayfly (Ephemeroptera) taxa identified in each replicate. The three replicates are then averaged for this metric.
Plecoptera (stonefly) taxa richness	Total number of unique stonefly (Plecoptera) taxa identified in each replicate. The three replicates are then averaged for this metric.
Trichoptera (caddisfly) taxa richness	Total number of unique caddisfly (Tricoptera) taxa identified in each replicate. The three replicates are then averaged for this metric.
Number of long-lived taxa	Total number of long lived taxa identified in each replicate. The three replicates are then averaged for this metric.
Number of intolerant taxa	Total number of unique intolerant taxa identified in each replicate. The three replicates are then averaged for this metric.
Percent tolerant individuals	Total number of tolerant individual counted in each replicate, multiplied by 100. Chironomids are not included in this metric. The three replicates are then averaged for this metric.
Number of clinger taxa	Total number of unique clinger taxa identified in each replicate. The three replicates are then averaged for this metric.
Percent predator individuals	Total number of predator individual counted in each replicate, multiplied by 100. Chironomids are not included in this metric. The three replicates are then averaged for this metric.

Percent dominance	The sum of individuals in the three(3) most abundant taxa in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The three replicates are then averaged for this metric.

Table 4.6: Ranges of the Ten Metric B-IBI Scores for Rating the Stream Condition

Ten Metric B-IBI Score	Stream Condition
46 – 50	Excellent
38 – 44	Good
28 – 36	Fair
18 – 26	Poor
10 - 16	Very Poor

Determining Sources of Bacteria

The ratios of fecal coliform (FC) to fecal streptococci (FS) for each sample in the Big Creek watershed during the 2008 and 2009 sampling, were computed and compared with ranges of FC/FS ratios associated with different types of fecal sources as described by Geldreich and Kenner (1969). A ratio greater than 4.0 indicates human pollution, while a ratio less than or equal to 0.7 indicates non-human pollution (Geldreich and Kenner, 1969).

4.2 Findings

Historic Long-term Water Quality

High levels of E.coli, fecal coliform, and pseudomonas were found in the majority of water samples collected during the study period. The average values of these four indicator bacteria exceeded the MOE guidelines by as much as 3.5 times. The pseudomonas results indicated that a significant quantity of the fecal pollution observed at Holiday Beach and the Big Creek watershed was of human and animal origin. The results also suggested that Holiday Beach is also receiving fecal pollution from a source(s) other than the Big Creek watershed.

Of the six chemical parameters (phosphorus, TKN, nitrite, nitrate, chloride and pH), phosphorus and TKN concentrations were found to exceed the MOE guidelines in over 80% of the water samples. The remaining parameters were found to be within the recommended limits. Phosphorus and TKN have organic sources (including feces) and hence these results also suggest excessive fecal contamination within Holiday Beach and the Big Creek watershed.

The results of the Phase-I Study indicated that sources of fecal contamination were likely manure management practices within the Big Creek watershed. Estimated contaminant loads using the CURB algorithms from the Phase-II study suggested that faulty septic systems were the major sources of the bacterial loadings (89%) received by the watercourses within the Big Creek watershed. However the relative contributions of bacteria to Holiday Beach from various sources could not be established from the data collected. It was estimated that soil erosion contributed approximately 88% of the calculated phosphorus load to Big Creek. This report also concluded that the Big Creek marsh is critical in terms of the movement of bacteria to Holiday Beach, as bacteria can survive in the marsh sediment for many months during fall and early winter. It was recommended that more data be collected in order to understand the relationship between wind direction and flow rate at the outlet of the marsh. The impact of loadings from the Detroit River on Holiday Beach could not be determined through this study.

Provincial Water Quality Monitoring Network (PWQMN)

Total Phosphorus (TP) concentrations exceeded the Provincial Water Quality Objective (PWQO) limit of 0.03 mg/L in almost all of the 148 samples collected between 1964 and 1996. The data show a significant increasing trend in TP concentration between 1964 to 1970 and 1982 to 1996.

Nitrate concentrations exceeded the Canadian Environmental Quality Guideline (2.93 mg/L nitrate-N) in half of the 223 samples collected. No significant trend was observed in the data between 1964 and 1971, while median nitrate concentrations for the periods 1964-1971, 1982-1990 and 1991-1996 were significantly different and showed an increasing trend.

Total Suspended Solids (TSS) varied from 3 mg/L to 244 mg/L during 1964 and 1996 at the PWQMN sites in the Big Creek watershed. Over 76% of the 232 samples collected during this period exceeded the benchmark value of 25 mg/L. Also, a significant increasing trend was observed in the data from 1964 to 1971 as well as in the data from 1982 to 1994.

Chloride concentrations at the PWQMN sites in the Big Creek watershed ranged between 3.3 mg/L and 2315 mg/L. The highest concentrations were observed during 1989 to 1995, while concentrations during 1985 to 1988 were well below the PWQO limit of 210 mg/L. The highest number of exceedance occurred during May to December as compared to the winter months (e.g. January, February, March and April), which indicate that there were other sources of chlorides to flowing waters in the Big Creek watershed, than just road salt.

Microbial monitoring was conducted on an irregular basis during 1964 to 1995. E.coli was not monitored at the PWQMN sites during this period. Total coliform (TC) values varied significantly during 1964 to 1971, and remained consistently high during 1964 to 1971 and from 1982 to 1994. Fecal coliform (FC) levels were found consistently high during the period of 1981 to 1996. Pseudomonades were monitored from 1981 to 1995. The overall microbial concentrations indicate severe bacterial contamination of human origin. The potential sources of these bacteria and pathogen include human and animal feces and wastewaters.

The table 4.7 summarizes the obvious visual trends observed in the selected water quality parameters based on three distinct time periods between 1964 and 1996.

Table 4.7: Summary of Trends/Changes in the PWQMN Data

Parameter	Trend (1964 to 1971)	Trend (1982 to 1990)	Trend (1991 to 1996)	Overall Trend
TP	↑	-	↑	↑
Nitrate	↑	↑	↑	↑
Chloride	NA	↑	↑	↑
TSS	↑	↑	↑	↑

↑ Increase - Steady NA not applicable

Current Water Quality

The current study conducted over two years included surface water quality monitored at 10 sites in the Big Creek watershed. The overall results of monitoring are divided into: tributary, marsh and nearshore water quality.

Tributary (In Land) Water Quality

Water Temperature

Temperature is an important factor as it dictates the type of aquatic life that can live in a stream. Insects, zooplankton, phytoplankton, fish, and other aquatic species all have a preferred temperature ranges. Higher water temperature levels can also impact oxygen saturation resulting in reduced dissolved oxygen levels which may result in decreased metabolic rates, growth and reproduction of freshwater fish (Gordon et al., 1994 as sited in LPCRA 2005 Technical Report). In the in land tributary sites, on average, water temperature did not raise above the 24C threshold between cool and warm water fish species (Coker et al., 2001; Stoneman and Jones, 1996 as cited in LPCRA 2005 Technical Report). Water temperatures among the five sites, BC-1, BC-2, BC-3, BC-4 and BC-5, were not statistically different (p=0.59). However, site BC-N, which is immediately downstream of the urbanized portion (Amherstburg) of the watershed, was found to have significantly higher water temperature than those found at the other five sites in the watershed (p=0.0006).

pH

As per the PWQO, the pH in the aquatic systems should be maintained within the range of 6.5 to 8.5 to protect aquatic life and for recreational purposes. The pH varied drastically above and below the recommended range at all the in land tributary sites, except BC-N. Site BC-4 showed the highest number of pH records above 8.5 which is the upper limit of the PWQO. These higher pH observations were observed during the summer months (June, July and August) and were highly correlated to the higher water temperatures. Higher pH values suggest higher photosynthetic activities in the stream (Wurts and Durborow, 1992). This is corroborated by the fact that excessive algal and other phytoplankton growth was observed by the sampling crew at this site.

Dissolved Oxygen (DO)

During the 2008-2009 study period, dissolved oxygen (DO) levels fell below 4.0 mg/L at least 5% of the time at all the in-stream sites except BC-N and BC-4, as shown in Figure 4.4. In general, DO levels in aquatic systems are impacted by atmospheric pressure and water temperature. As consistent with the flat topography of the Essex region, the sampling sites within the Big Creek watershed are at the same elevation and hence DO levels in the Big Creek watershed are mostly controlled by temperature and other physical and chemical characteristics (e.g. extent of riparian vegetations, water levels, water velocities, nutrient levels and photosynthetic activities). The data indicate that in general the sites with continuous visible flows show higher DO levels as compared to the sites with stagnant water. Figure 4.5 shows seasonal impacts on DO levels in the Big Creek watershed. It is evident from the graph that majority of low DO observations occurred during the summer months of June, July and August, while a small amount of DO exceedance occurred during the Fall month, and no exceedance occurred during the Spring months.

Figure 4.4: Box and Whisker Plots showing the Range of Data for Dissolved Oxygen in the Big Creek Watershed during 2008-2009

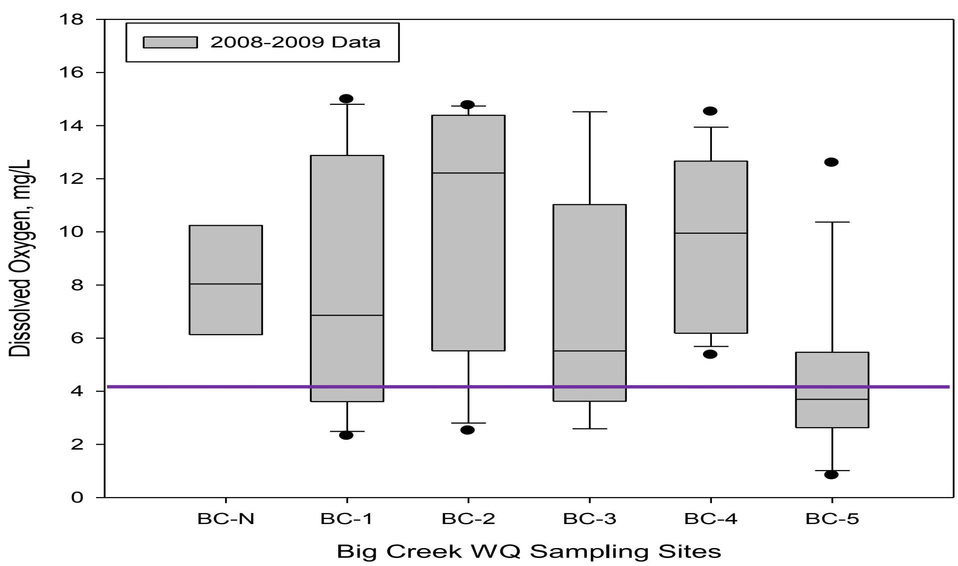
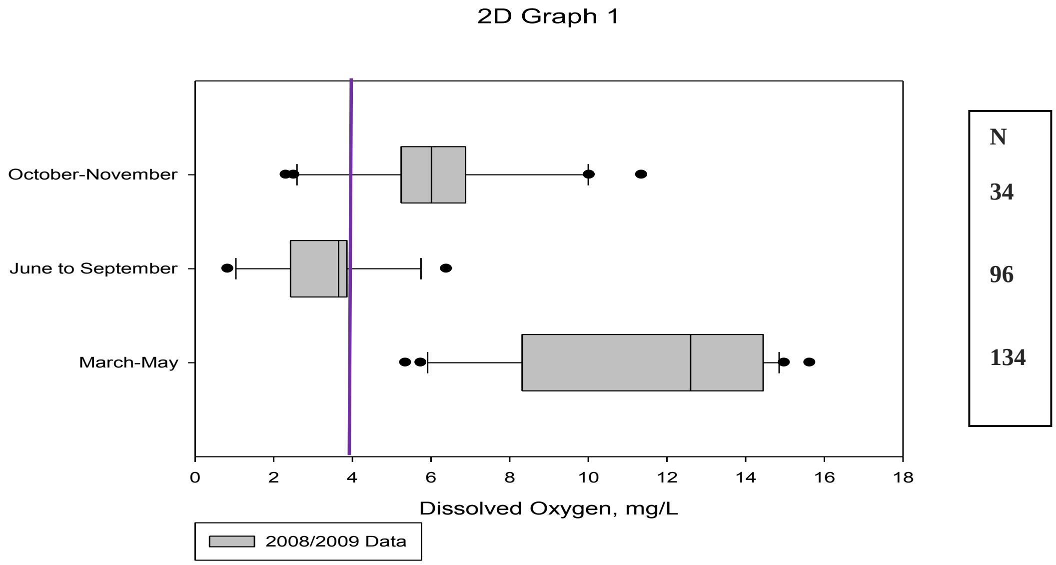


Figure 4.5: Box and Whisker Plots showing the Range of Data for Dissolved Oxygen on Seasonal Basis in the Big Creek Watershed during 2008-2009



Total Phosphorus

Total phosphorus (TP) concentrations observed at the six monitoring sites in the Big Creek watershed during 2008 and 2009 are shown in Figure 4.6. TP concentrations at these sites ranged from as low as 4µg/L at BC-4 to as high as 980µg/L at BC-4. Over 97% of samples exceeded the PWQO limit of 30µg/L. No significant differences were observed between any of the four sites on the east branch of Big Creek (p=0.42), while TP levels at BC-5 were significantly higher than those of the rest of the sites (p=0.003). TP concentrations observed in the west branch of the creek were found to be significantly higher than those in the east branch. A slight increasing trend from upstream to downstream was also observed in the TP data; however, it was not statistically significant.

TP data for individual sites was also plotted in terms of regular and wet weather sampling regime as shown in Figure 4.7. It is evident that there is no clear pattern observed in terms of differences between wet weather and regular water samples. Overall results showed no significant difference between wet weather and regular weather TP concentrations (p=0.58), also TP levels at BC-1, BC-3, and BC-4 showed no significant difference in wet weather and regular samples (p=0.44). At the sites BC-N and BC-5, TP levels in regular samples were significantly higher than those in wet weather samples (p=0.003), while the site BC-2 wet weather TP levels were significantly higher than regular TP levels (p=0.006). In general, the TP levels found in the Big Creek watershed are typical of highly agricultural landscape of southwestern Ontario. Potential sources may include run-off from fertilized agricultural lands within the watershed and urban inputs (mainly lawn fertilizer) from the Town of Amherstburg.

Figure 4.6: Box and Whisker Plots showing the Range of Data for Total Phosphorus in the Big Creek Watershed during 2008-2009

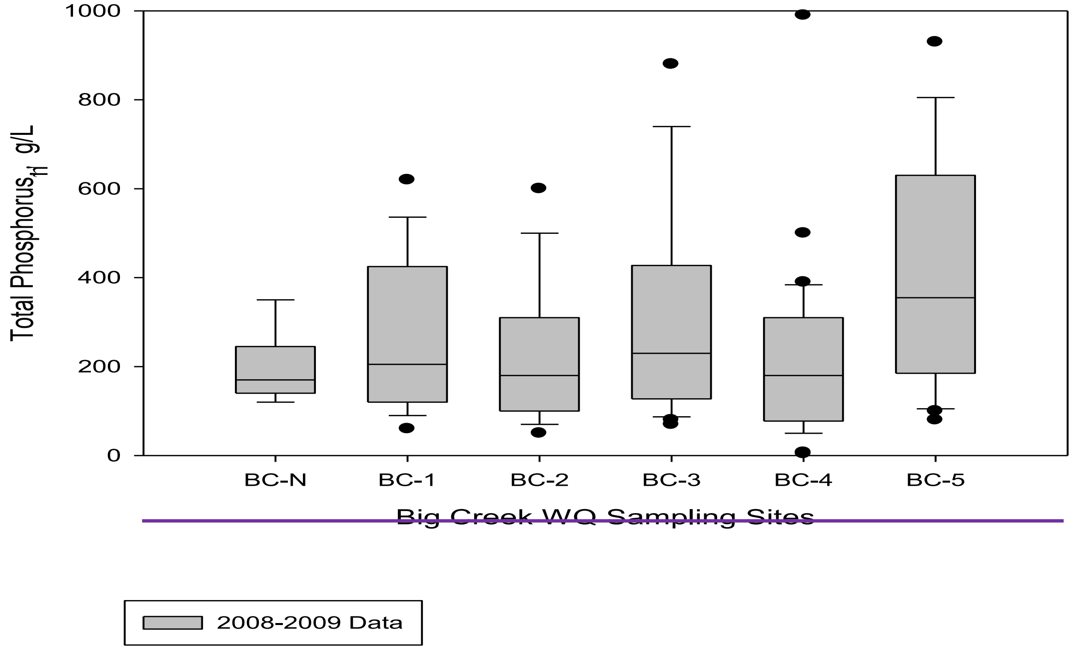
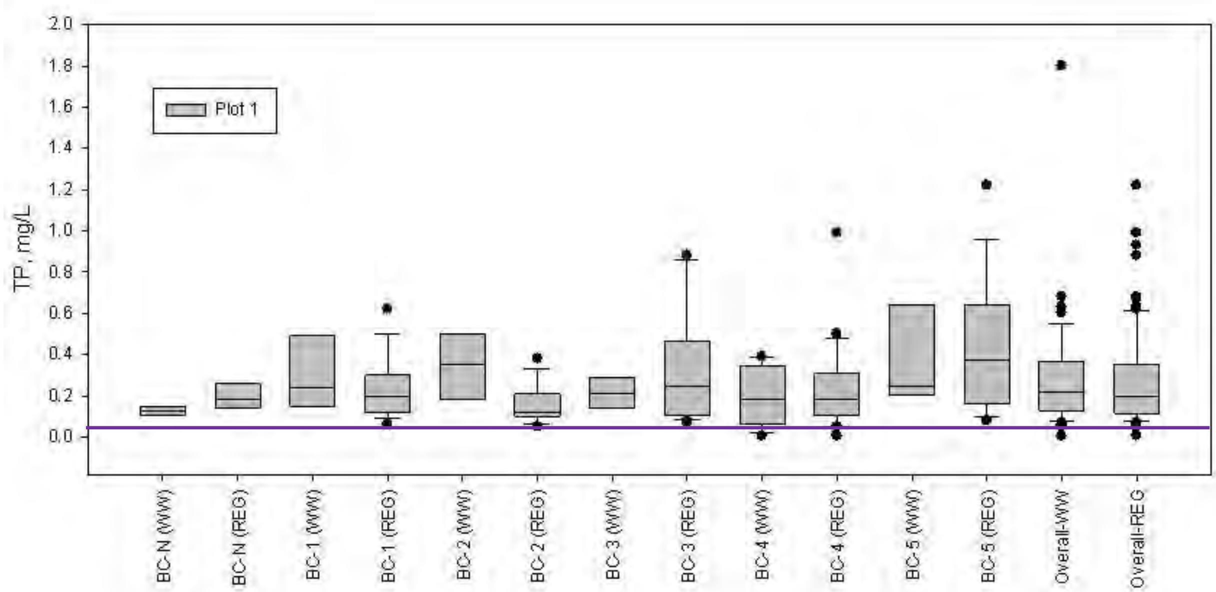


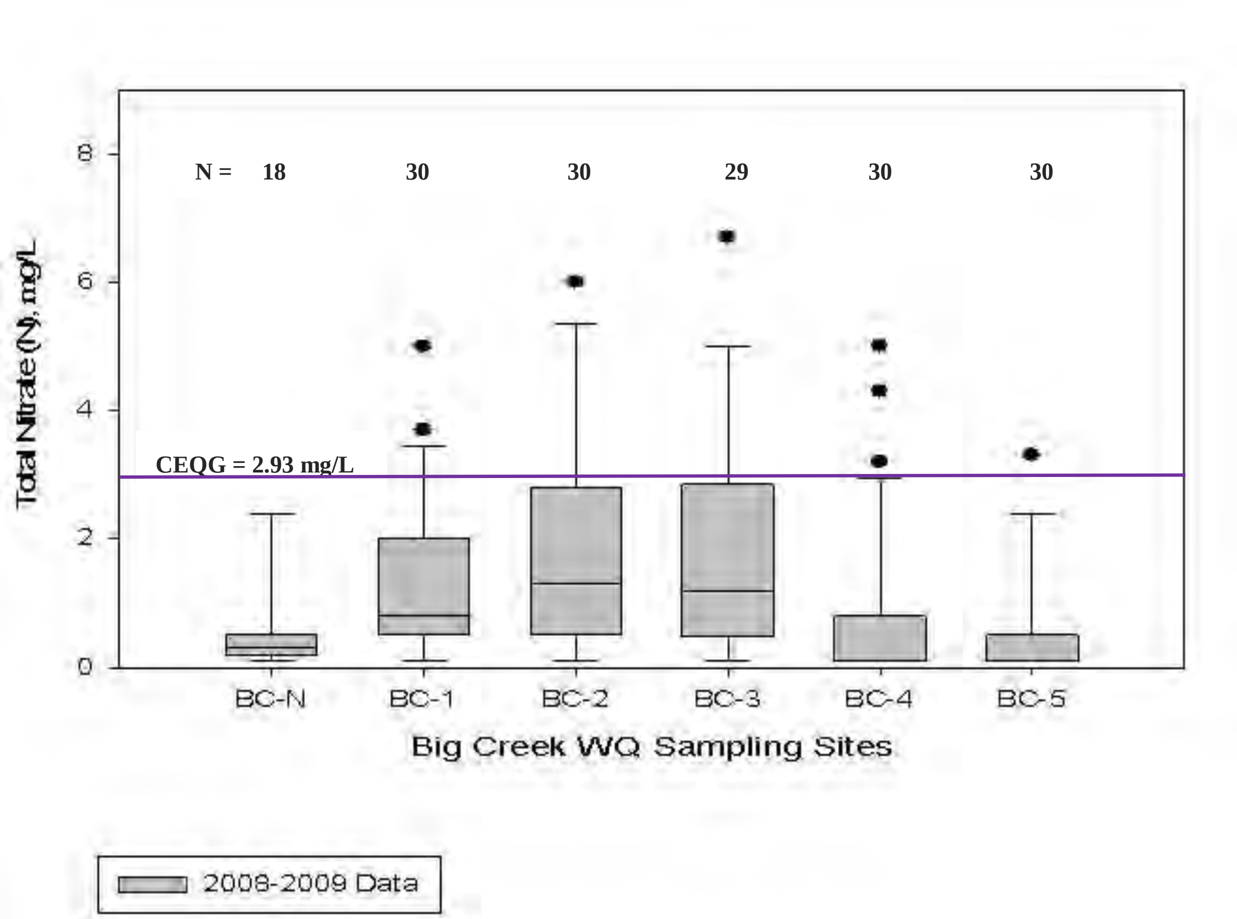
Figure 4.7: Box and Whisker Plots showing the Range of Data for Total Phosphorus in terms of Regular and Wet Weather Events during 2008-2009



Nitrate

Nitrates are naturally occurring and ubiquitous in the environment. They are a major constituent in most fertilizers. Canadian Environmental Quality Guideline (CEQG) has set a limit of 2.93 mg/L for the nitrate ion (NO_3^--N) for the protection of aquatic life (EC, 2002). Nitrate is considerably less toxic than ammonia or nitrite (Colt and Armstrong, 1981). Nitrate levels in the Big Creek watershed were generally below the CEQG limit, however some of the sites showed an exceedance during the 2008 and 2009 monitoring period, as shown in Figure 4.8. At all the sites, only 10% of samples collected over the 2 year time period exceeded the CEQG limit. Nitrate levels observed in the west branch (BC-N, BC-5) of the creek are significantly lower than those of the east branch (BC-1, BC-2, BC-3 and BC-4) ($p=0.006$).

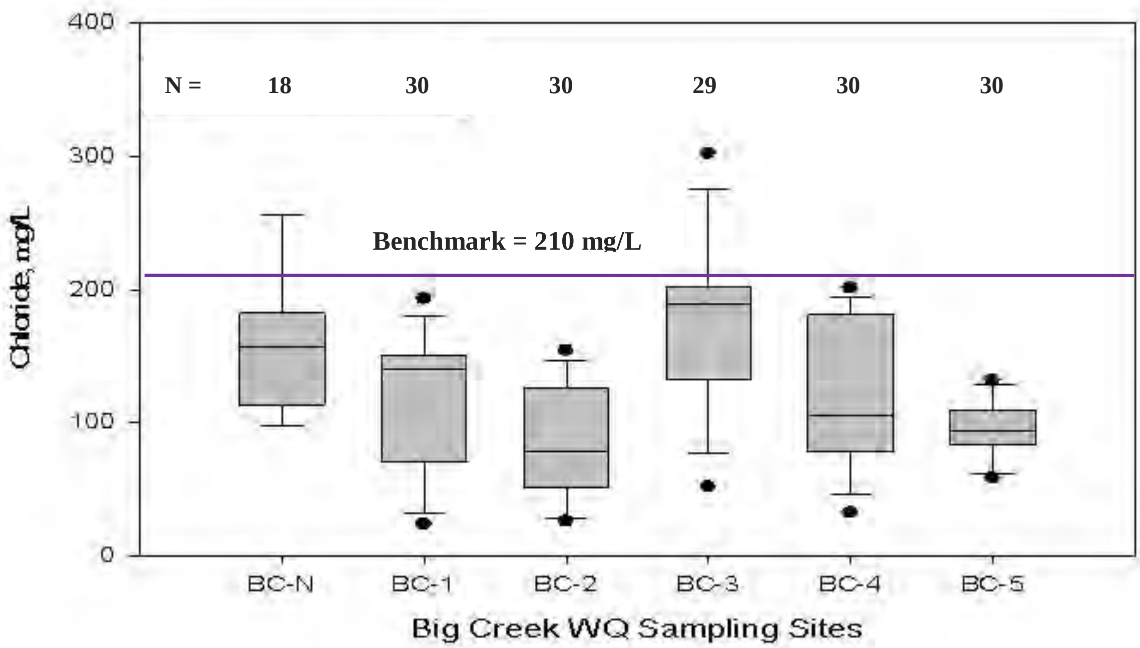
Figure 4.8: Box and Whisker Plots showing the Range of Data for Total Nitrate in the Big Creek Watershed during 2008-2009



Chloride

Chloride at the tributary sites was monitored from March 2009 to November 2009. The results are plotted in Figure 4.9. In general, chloride concentrations ranged from as low as 13 mg/L (BC-1) to 302 mg/L at BC-3, except a one-time unusually high concentration of 7,090 mg/L at BC-1 on May 5th, 2009. This unusually high concentration of chloride could be attributed to leakage from the soda ash storage pond just upstream of BC-1, location shown in Figure 4.10. Chloride levels at the 3 headwaters sites (BC-N, BC-1, and BC-3) that have relatively high urban land use, are significantly higher than the remaining three downstream sites (p=0.003).

Figure 4.9: Box and Whisker Plots showing the Range of Data for Chloride in the Big Creek Watershed during 2008-2009



Monthly average chloride concentrations for the Big Creek watershed in 2009 were not significantly different during 2009. That is, the March 2009 chloride concentrations were statistically the same as other months in 2009 (p=0.46 to 0.56) (Figure 4.11). This suggests that there are other sources of chloride in the Big Creek watershed beyond road salt application. The marsh sites and the lake sites also have significantly lower chloride concentrations when compared to the in-stream sites.

Figure 4.10: Map showing Location of the Soda Ash Basin in Relation to Water Quality Sites

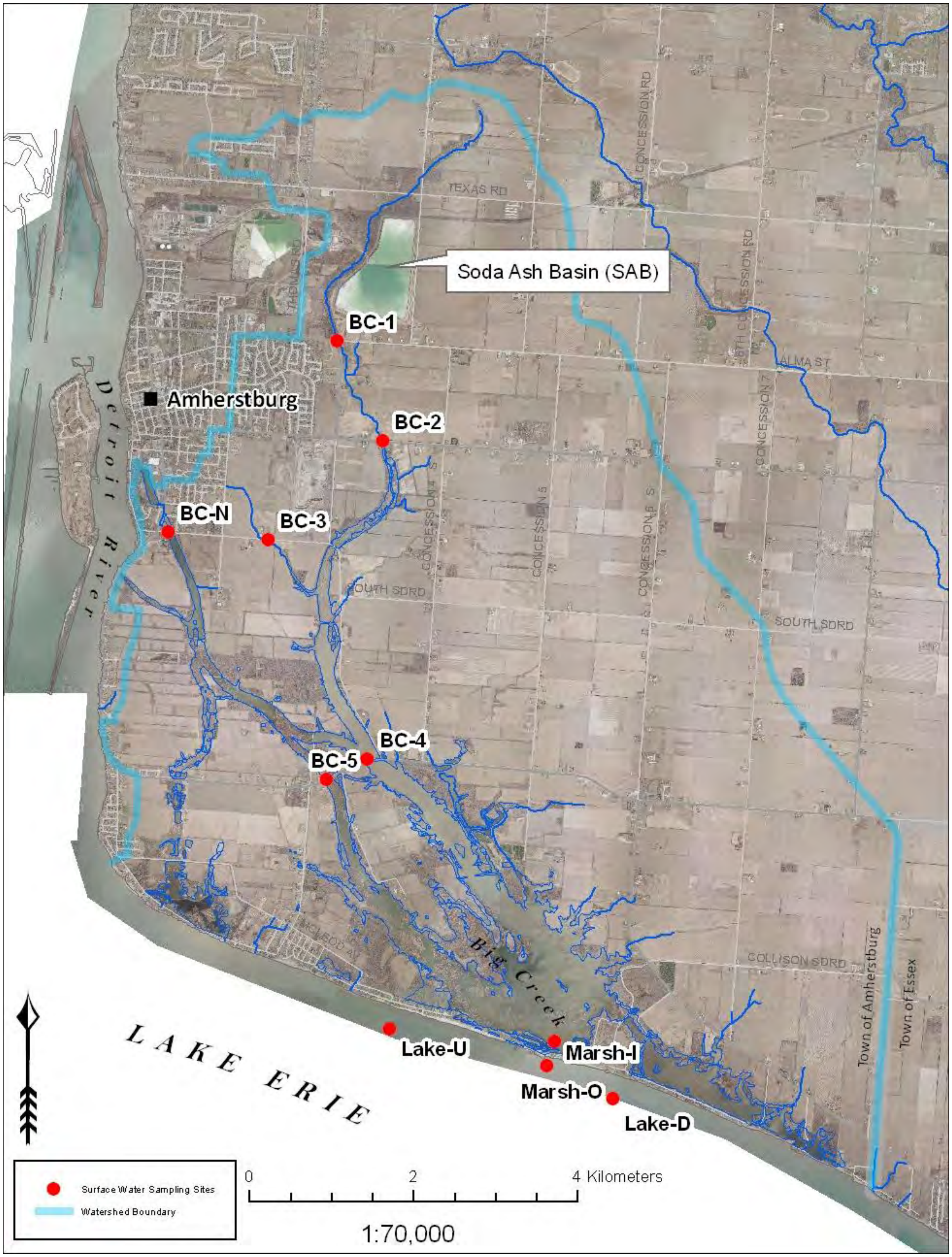
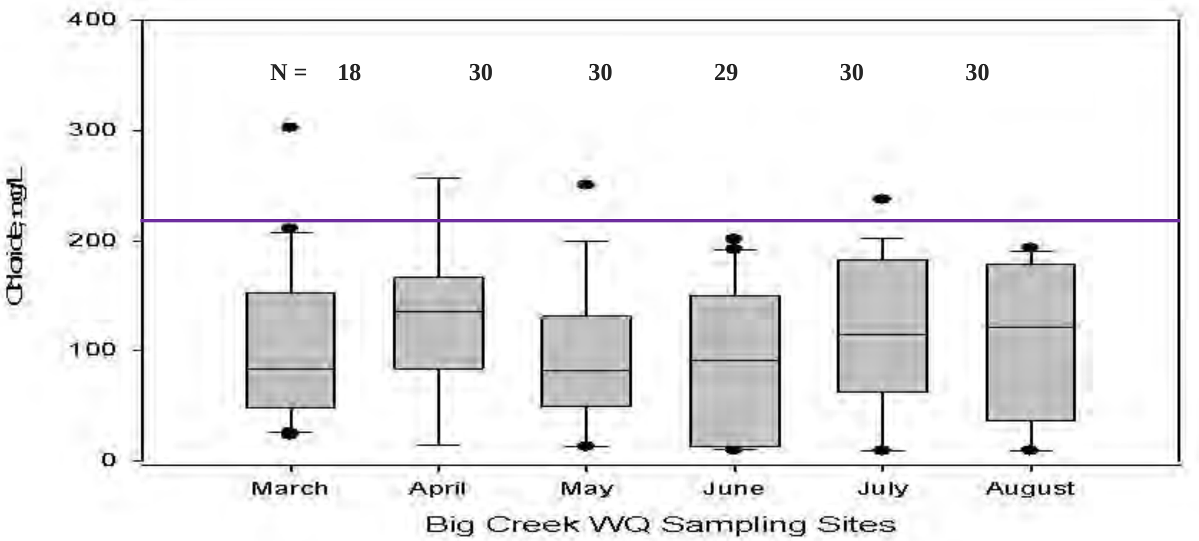


Figure 4.11: Box and Whisker Plots showing the Range of Data for Chloride on Monthly Basis in the Big Creek Watershed during 2008-2009

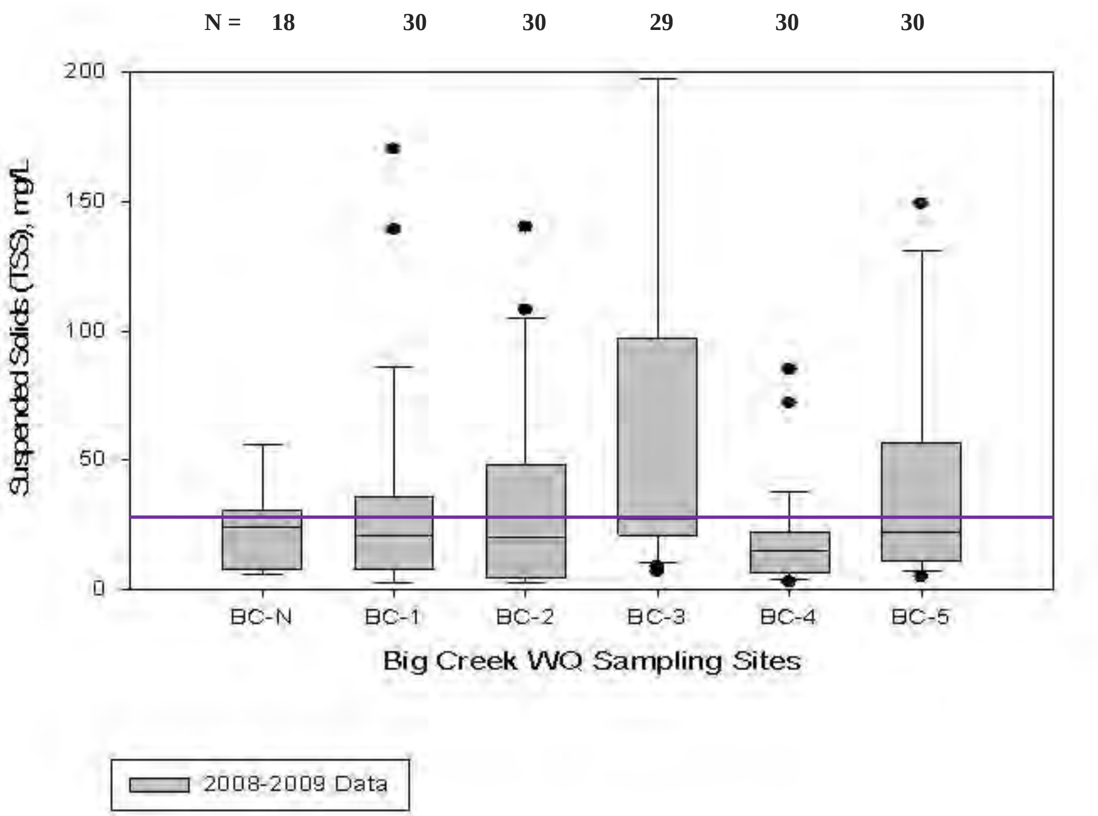


Total Suspended Solids

Total Suspended Solids (TSS) is comprised of organic and mineral particles that are transported in the water column. TSS is closely linked to land erosion and to erosion of river channels. TSS can be extremely variable, ranging from less than 5 mg/L to extremes of 30,000 mg/L in some rivers. TSS is not only an important measure of erosion in river basins; it is also closely linked to the transport through river systems of nutrients (especially phosphorus), metals, and a wide range of industrial and agricultural chemicals.

Total suspended solids (TSS) in the Big Creek watershed ranged from as low as 3 mg/L to as high as 418 mg/L during 2008 and 2009. The mean TSS concentrations at all the sites were below the benchmark 25 mg/L. TSS concentrations at BC-3 and BC-5 were found to be statistically different and higher than those of other tributary sites (p=0.003). TSS concentrations observed in wet weather samples were significantly higher than those in regular weather samples at all the tributary sites in the watershed (p=0.001) (Figure 4.12).

Figure 4.12: Box and Whisker Plots showing the Range of Data for Total Suspended Solids in the Big Creek Watershed during 2008-2009

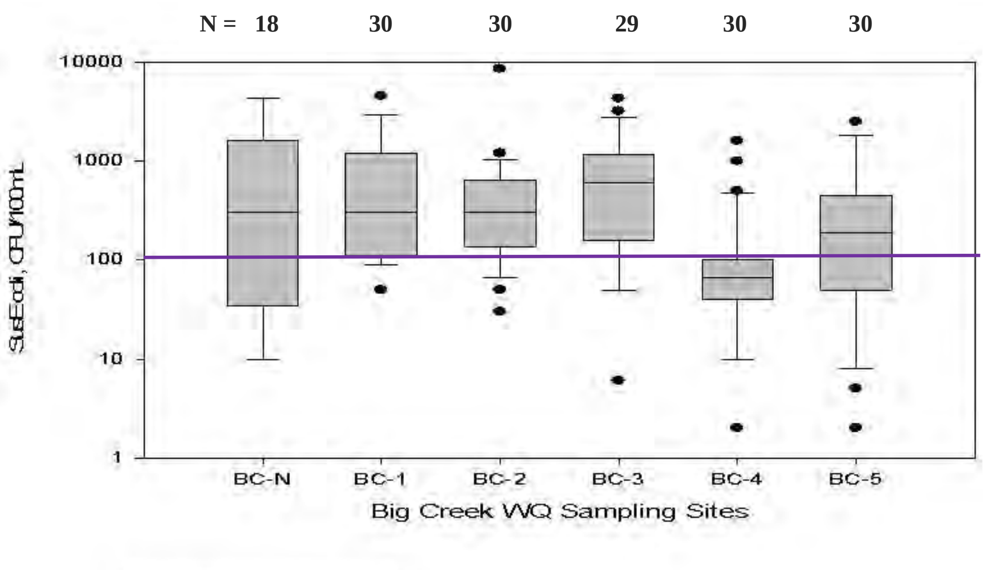


E.coli

Escherichia coli or E.coli is a type of coliform bacteria commonly found in the intestines of animals and humans. Most strains of E.coli do not cause illness in healthy humans and are beneficial to the synthesis of vitamins. Some strains, however, cause cramps and diarrhea in humans. Health organizations and water quality professionals across the world have selected E.coli as the most reliable indicator for the bacteriological quality of drinking and recreational water. During rainfalls, snowmelts, or other types of precipitation, E.coli may be washed into creeks, rivers, lakes, or groundwater.

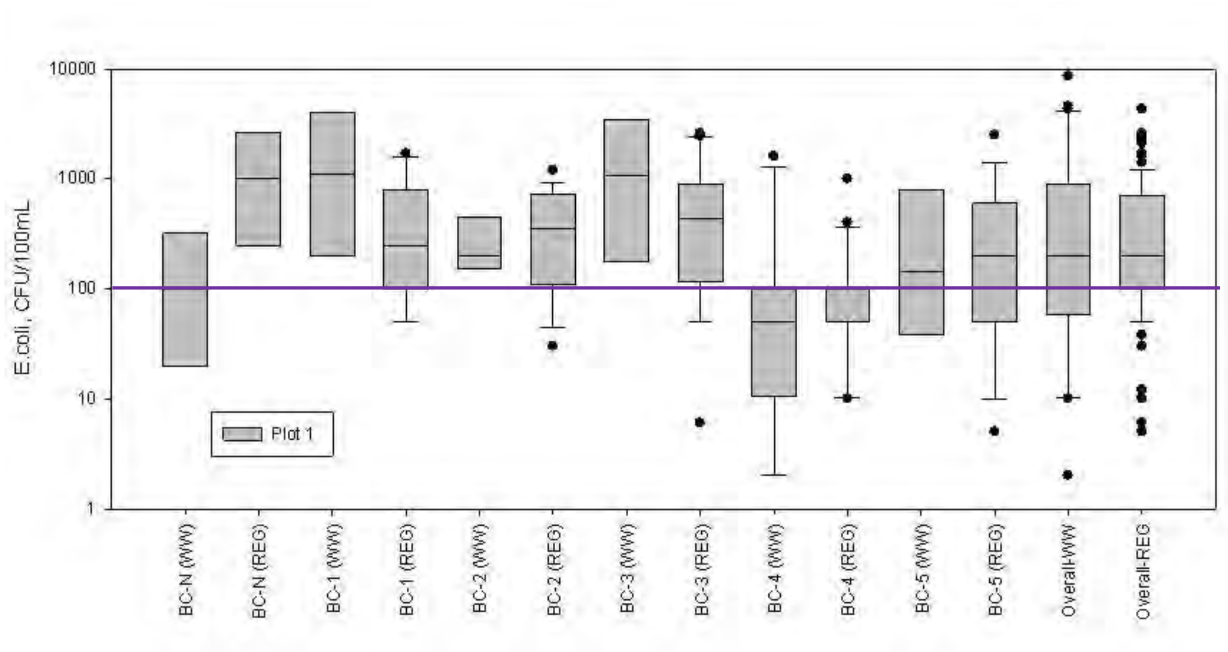
Figure 4.13 shows the variation in E.coli levels at all the tributary sites in the Big Creek watershed. It is evident from the graph that E.coli levels varied dramatically at all the sites in the watershed during 2008-2009. These levels ranged from below 2 CFU/100mL to 8,600 CFU/100mL. Mean E.coli levels at all the sites, except BC-4, were above the recreational water quality guideline of 100 CFU/100mL. E.coli levels at BC-4 were significantly lower than those at other sites (p=0.004), while E.coli levels at BC-3 were significantly higher than those found at all other sites in the watershed (p=0.002). E.coli concentrations for wet weather and regular samples at all the tributary sites are shown in Figure 4.14. It is evident from the plot that overall the median E.coli levels for wet weather samples were statistically the same as those found in regular weather samples (p=0.66); however, at the four sites (BC-N, BC-1, BC-2 and BC-4), there was a significant difference in E.coli levels between wet weather and regular samples (p values ranged between 0.002 to 0.005), although the differences were not consistently in one direction (e.g., WW > Reg).

Figure 4.13: Box and Whisker Plots showing the Range of Data for E.Coli in the Big Creek Watershed during 2008-2009



PWQO = 100 CFU/100 mL (recreational Guideline)

Figure 5.14: Box and Whisker Plots showing the Range of Data for E.coli in terms of Regular and Wet Weather sampling in the Big Creek Watershed during 2008-2009



Pesticides

All sites in the Big Creek watershed were sampled for pesticides. Samples were collected three times during the study period, at five month intervals. Results for pesticides are summarized in Table 4.8. While 2, 4-D and glyphosate were found in low concentrations at the marsh inlet site, atrazine was found above the PWQO at most tributary sites and at the marsh inlet site.

Table 5.8: Summary of Pesticides Concentrations observed in the Big Creek Study Area (2008-2009)

Sampling Location	Number of Samples	Atrazine	2,4-D	Metolachlor	Glyphosate
		1.8 μg/L[1]	4 μg/L[1]	3 μg/L[1]	65 μg/L[2]
BC- N	3	2.8 (±1.32)	BDL	BDL	1.5 (±1.32)
BC - 1	3	11.8 (±3.56)	BDL	BDL	4.8 (±1.32)
BC - 2	3	12.3 (±2.41)	BDL	BDL	2.1 (±1.32)
BC - 3	3	11.2 (±0.92)	BDL	BDL	6.2 (±1.32)
BC - 4	3	6.8 (±2.62)	BDL	BDL	BDL
BC - 5	3	BDL	BDL	BDL	BDL
Marsh - In	2	1.2 (±1.26)	2.0 (±1.32)	BDL	1.5 (±1.32)
Marsh - Out	2	ND	ND	ND	ND
Lake - Up	3	ND	ND	ND	ND
Lake - Down	3	ND	ND	ND	ND

[1]PWQO (Provincial Water Quality Objective); [2]Canadian Council of Ministers of the Environment (CCME) guideline;

ND= Not Detected; BDL=Below Detectable Limit

According to the Health Canada website, atrazine is used extensively in Canada as a pre and post emergence weed control agent, primarily for corn but also for rapeseed and vegetation control in non-cropland and industrial areas. Further, atrazine (or its by-products) is one of the most frequently detected pesticides in surface and well water and contamination incidents have been reported in nearly all of Canada. Atrazine contamination has been reported in Ontario along with several other provinces (Hiebsch, S.C. Ottawa, 1988). In 1985, 85% of ambient water samples in one area of southwestern Ontario were found to be contaminated with traces of atrazine (Alachlor Review Board Report. October, 1987).

Metals

All sites in the Big Creek watershed were sampled for metals. Samples were collected three times during the study period, at 5 month intervals. The heavy metals analyzed included; arsenic, cadmium, chromium, iron, lead and zinc. Results are summarized in Table 4.9. It is evident from the results that water quality in the watershed has high levels of iron exceeding the PWQO of 300 µg/L in 100% of the samples, which is typical of surface water in the Essex region. Concentration of iron ranged from as low as 439 µg/L to as high as 2,780 µg/L. Copper levels exceeded the PWQO criteria at the site (BC-3) just downstream of the urban land in the Big Creek watershed. Cadmium exceeded the PWQO benchmark at the inlet of the marsh. The majority of water samples in Lake Erie and the marsh showed metals below the detectable limits, with just a few exceptions.

Table 4.9: Summary of Selected Metals Concentrations in the Big Creek Study Area (2008-2009)

Sampling Location	No. of Samples	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Zinc
		100 µg/L[1]	0.2 µg/L[1]	1 µg/L[1]	5 µg/L[1]	300 µg/L[1]	5 µg/L[1]	30 µg/L[1]
BC- N	3	2.8 (±1.32)	BDL	BDL	1.5 (±1.32)	581 (±142)	BDL	BDL
BC - 1	3	11.8 (±3.56)	BDL	BDL	4.8 (±1.32)	1,735 (±345)	0.4 (±1.32)	16.1 (±1.32)
BC - 2	3	12.3 (±2.41)	BDL	BDL	2.1 (±1.32)	924 (±142)	BDL	19.3 (±1.32)
BC - 3	3	11.2 (±0.92)	BDL	BDL	6.2 (±1.32)	971 (±112)	2.3 (±1.32)	15.1 (±1.32)
BC - 4	3	6.8 (±2.62)	BDL	BDL	BDL	724 (±142)	0.7 (±1.32)	5.0 (±1.32)
BC - 5	3	BDL	BDL	BDL	BDL	2,605 (±142)	BDL	BDL
Marsh - In	2	1.2 (±1.26)	2.0 (±1.32)	BDL	1.5 (±1.32)	6 (±142)	BDL	BDL
Marsh - Out	2	BDL	BDL	BDL	BDL	581 (±142)	BDL	BDL
Lake - Up	3	BDL	BDL	BDL	BDL	581 (±142)	BDL	BDL

Lake - Down	3	BDL	BDL	BDL	BDL	581 (±142)	BDL	BDL

[1]PWQO (Provincial Water Quality Objective); BDL= Below Detectable Limit

Marsh and Lake Nearshore Water Quality

Water Temperature

Water temperatures at the nearshore site were statistically higher than those in the marsh (p=0.005). Water temperatures in the marsh were below the 24C threshold temperature at all the times while water temperatures at the nearshore sites rose above the threshold.

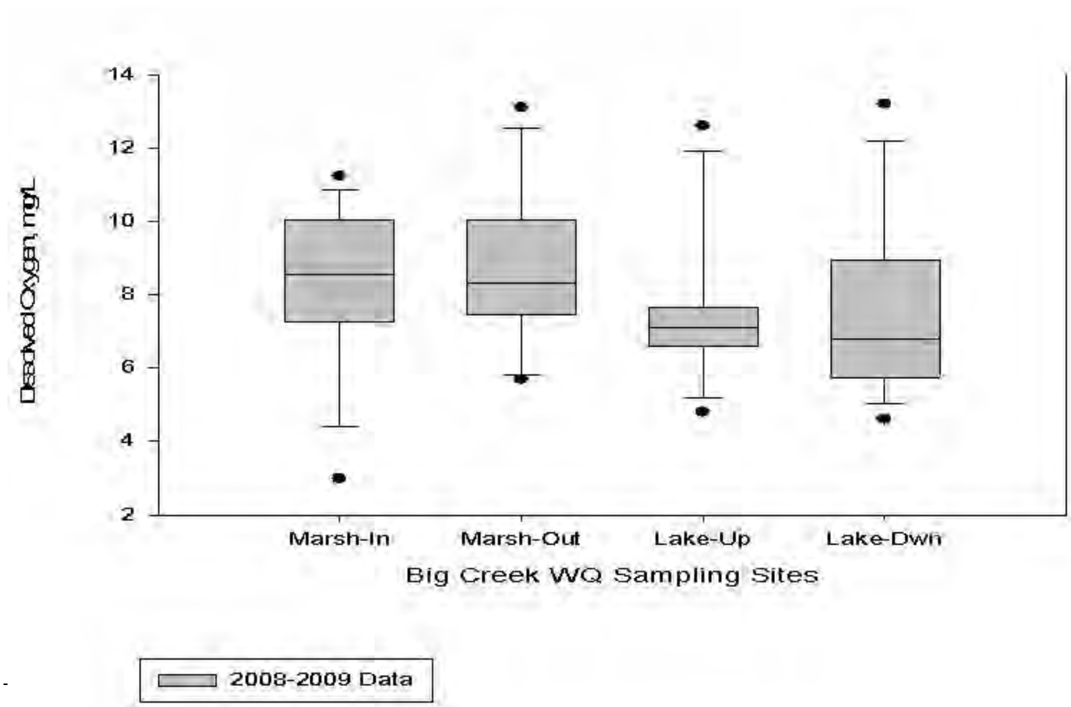
pH

The pH varied drastically above the recommended range of 6.5 to 8.5 at the nearshore sites, while the marsh sites showed the highest number of pH records within the limits of the PWQO. The majority of higher pH observations (i.e. pH above 8.5) at the nearshore sites was observed during the summer months (June, July and August) and was highly correlated to the higher water temperatures.

Dissolved Oxygen (DO)

Figure 4.15 shows the variation in dissolved oxygen levels at the marsh and nearshore sites in the Big Creek watershed during the 2008-2009 study periods. It is evident that DO levels were consistently high at all the times at all the sites. The seasonal distribution of the DO levels at these sites showed a slight variation, with the majority of low DO observations occurring during the summer months of June, July and August.

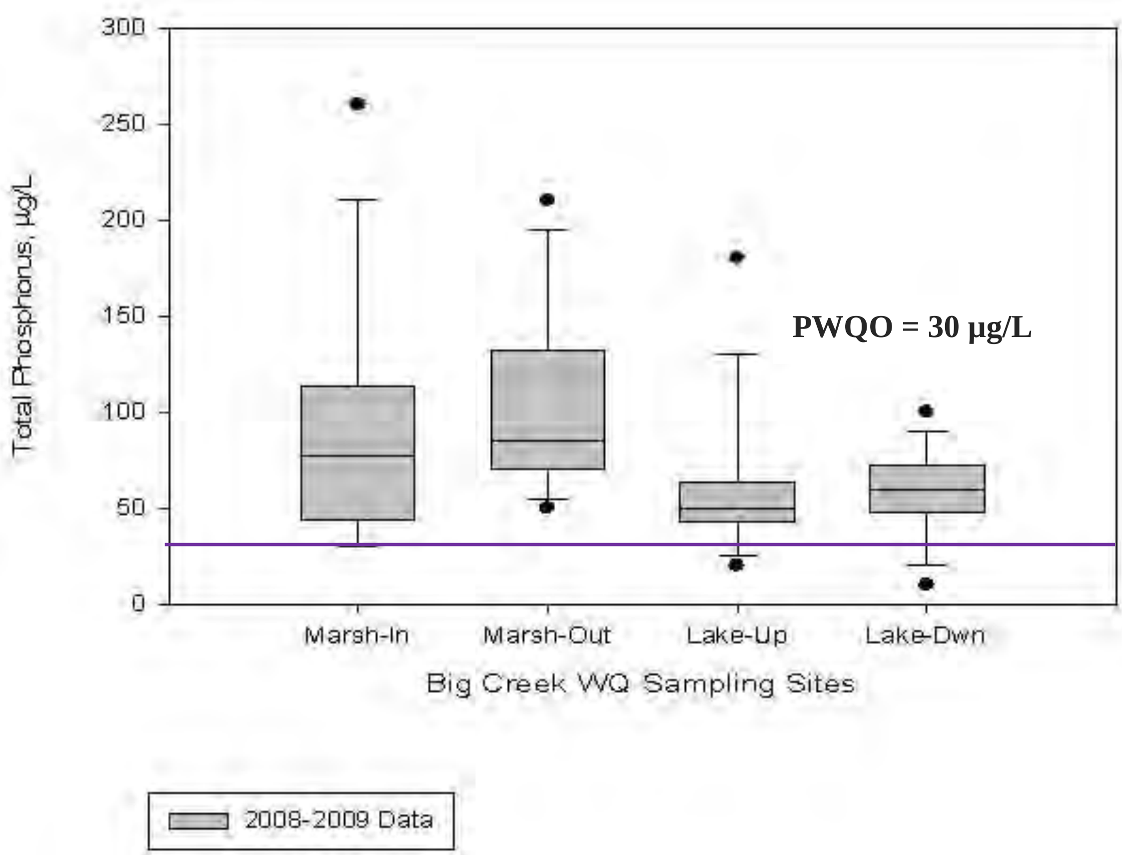
Figure 4.15: Box and Whisker Plots Showing the Range of Data for Dissolved Oxygen for the Marsh and Nearshore Sites in the Big Creek Study Area (2008-2009)



Total Phosphorus

Total phosphorus (TP) concentrations observed at the marsh and Lake Erie nearshore sites in the Big Creek watershed during 2008 and 2009 are shown in Figure 4.16. TP concentrations at these sites ranged from as low as 10 µg/L to as high as 260 µg/L, both at the marsh sites. Less than 20% of samples were below the PWQO limit of 30 µg/L. No significant differences were observed among the two sites in the marsh as well as among the two nearshore sites, while the overall TP concentrations at the marsh sites were significantly higher than those of the nearshore sites (p=0.006). In general, total phosphorus concentrations observed at the marsh and Lake Erie nearshore sites are significantly lower than those at the tributary (in land) sites during the same monitoring period.

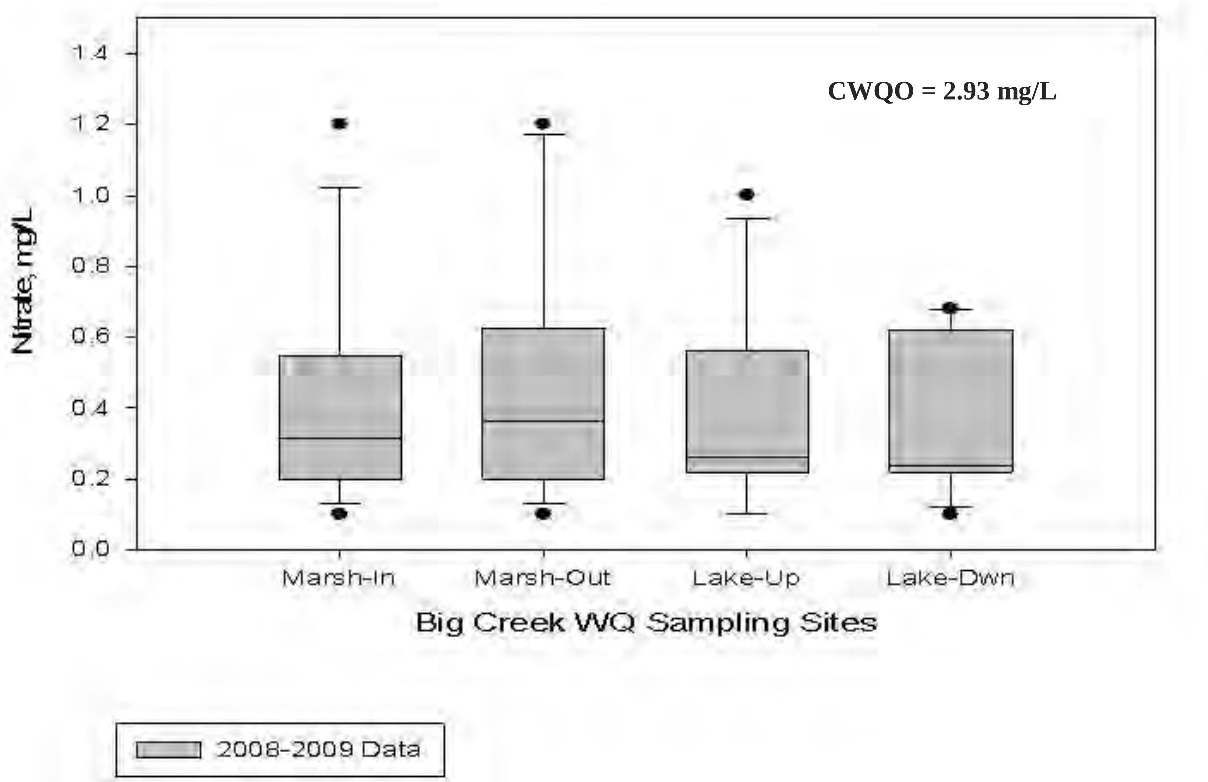
Figure 4.16: Box and Whisker Plots Showing the Range of Data for Total Phosphorus for the Marsh and Nearshore Sites in the Big Creek Study Area (2008-2009)



Nitrate

Nitrate levels in the Big Creek tributary in land sites were generally below the CEQG limit. The marsh and nearshore sites also showed very low concentrations of nitrate during 2008 and 2009 monitoring period. The CEQG limit was not exceeded during the study period at all sites. Nitrate concentrations ranged from 0.2 mg/L to 1.2 mg/L (Figure 4.17). Nitrate concentrations observed at the marsh sites were significantly higher than those found at the nearshore sites ($p=0.005$), while overall nitrate concentrations at these four sites were significantly lower than those found in the tributary sites ($p=0.0068$).

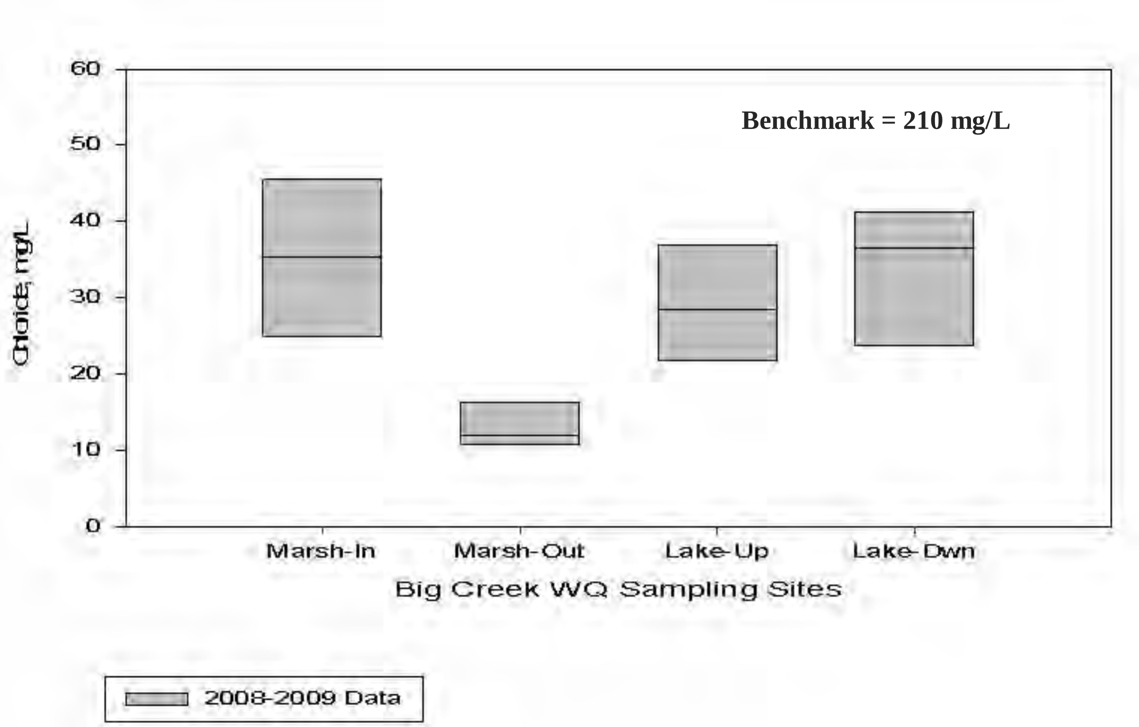
Figure 4.17: Box and Whisker Plots Showing the Range of Data for Total Nitrate for the Marsh and Nearshore Sites in the Big Creek Study Area (2008-2009)



Chloride

The marsh and nearshore sites were also monitored for chlorides during March 2009 to November 2009 (Figure 4.18). In general, chloride concentrations ranged from as low as 9.5 mg/L (Lake-down) to 45.5 mg/L at Marsh-in. Overall chloride concentrations for the marsh sites were statistically the same as the nearshore sites during 2009 ($p=0.69$). The marsh and nearshore sites showed significantly lower concentrations of chlorides compared to those observed at the tributary sites ($p=0.0069$).

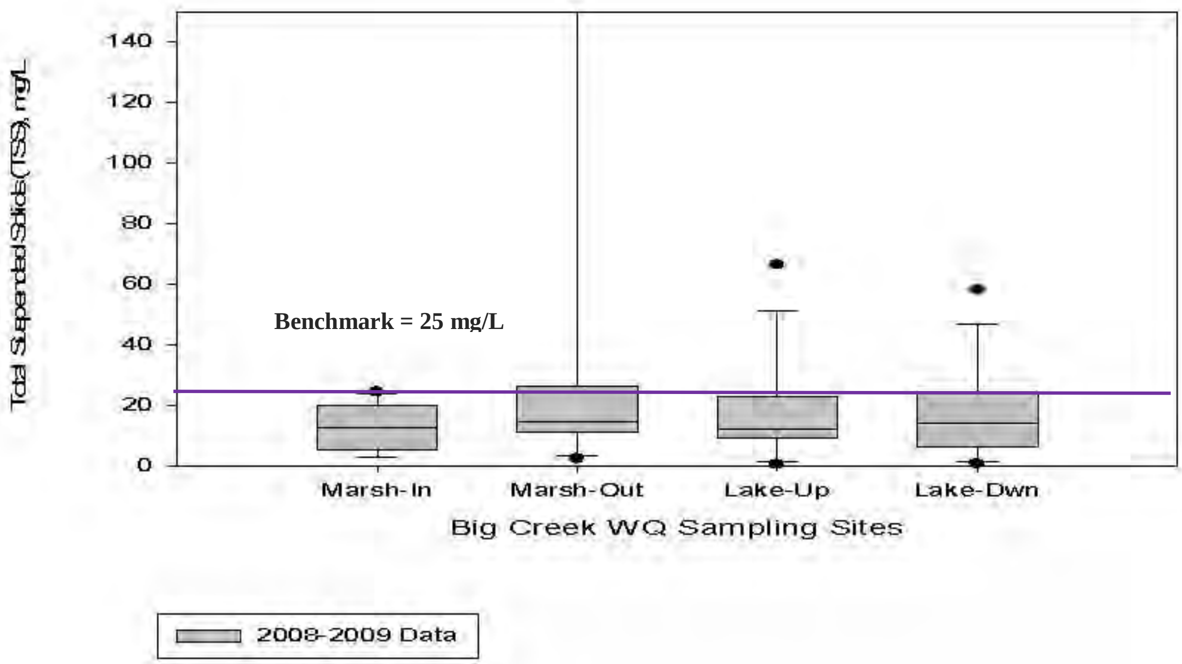
Figure 4.18: Box and Whisker Plots Showing the Range of Data for Chloride for the Marsh and Nearshore Sites in the Big Creek Study Area (2008-2009)



Total Suspended Solids

Total suspended solids (TSS) in the samples collected at the marsh and nearshore sites during 2008 and 2009 ranged from as low as 0.3 mg/L to as high as 235 mg/L (Figure 5.19). The mean TSS concentrations at all the four sites were below the benchmark 25 mg/L. TSS concentrations at the nearshore sites and at Marsh-out were found to be significantly higher than those at the Marsh-in site (p=0.001). No difference was observed in TSS concentrations between wet weather and regular weather samples at all these sites (p=0.56). The overall TSS concentration at these four sites was statistically different and lower than those observed at the tributary sites during the same study period.

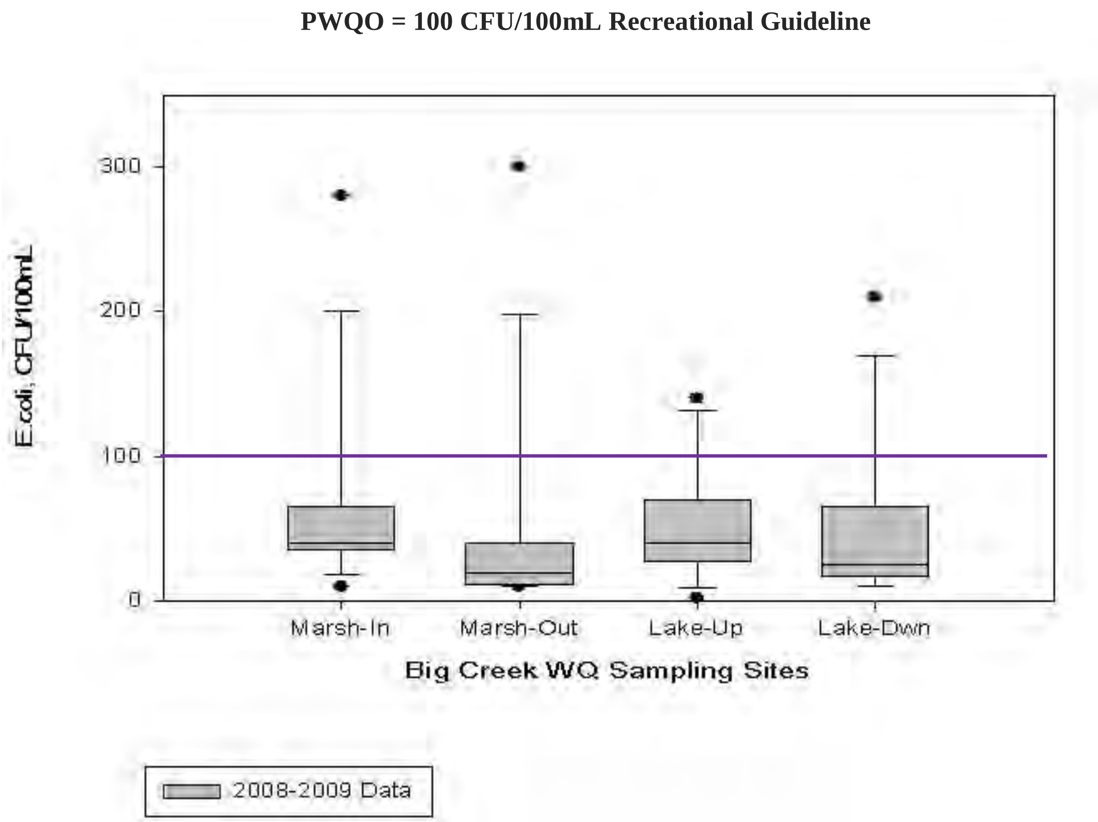
Figure 4.19: Box and Whisker Plots Showing the Range of Data for Total Suspended Solids for the Marsh and Nearshore Sites in the Big Creek Study Area (2008-2009)



Escherichia Coli

Figure 4.20 shows the variation in Escherichia coli (E. coli) levels at the marsh and nearshore sites. It is evident that E. coli levels varied within very narrow ranges at all these sites during 2008-2009. These levels ranged from below 2 CFU/100mL to 300 CFU/100mL. Mean E. coli levels at all the sites were below the recreational water quality guideline of 100 CFU/100mL. E. coli levels at the nearshore sites were significantly higher than those at the marsh sites (p=0.002). Overall E. coli levels at all the four sites were significantly lower than those found at the tributary sites in the Big Creek watershed (p=0.69). E. coli concentrations for wet weather and regular samples at the marsh and nearshore sites did not show statistical difference (p=0.56).

Figure 4.20: Box and Whisker Plots Showing the Range of Data for E.coli for the Marsh and Nearshore Sites in the Big Creek Study Area (2008-2009)



E. Coli Source Tracking

In this study, a simple fecal coliform/fecal streptococcus ratio method was employed to understand the potential sources of microbial contamination at various monitoring sites in the Big Creek watershed. A ratio greater than 4.0 indicates human pollution and a ratio less than or equal to 0.7 indicates non-human pollution (Geldreich and Kenner, 1969). The ranges of ratios for fecal coliform to fecal streptococcus are shown in Figure 4.21. These results are also summarized in Table 4.10. It is evident from the results that, except for site BC-3, the ranges of FC/FS ratio observed for all the sites were well below the 4.0 threshold value. The mean FC/FS ratio for the BC-3 was found to be greater than 4.0 indicating pollution from human fecal sources, while other sites showed FC/FS ratios below 2.0. It is important to note these results do not prove absence of human fecal contamination at the sites with FC/FS ratio < 4.0. Rather, they provide rapid results in terms of the extent of fecal coliform in the samples, as human feces contain higher fecal coliform, while animal feces contain higher levels of fecal streptococci. There are limitations to the above findings in that different fecal streptococci species have different survival rates and there have been changes in detection methods. Hence these results should be used to scope and determine the focus of future studies on E. coli source tracking in the Big Creek watershed.

Figure 4.21: Box and Whisker Plots Showing the Ranges of FC/FS Ratios Observed the Tributary Sites in the Big Creek Watershed (Fall 2009)

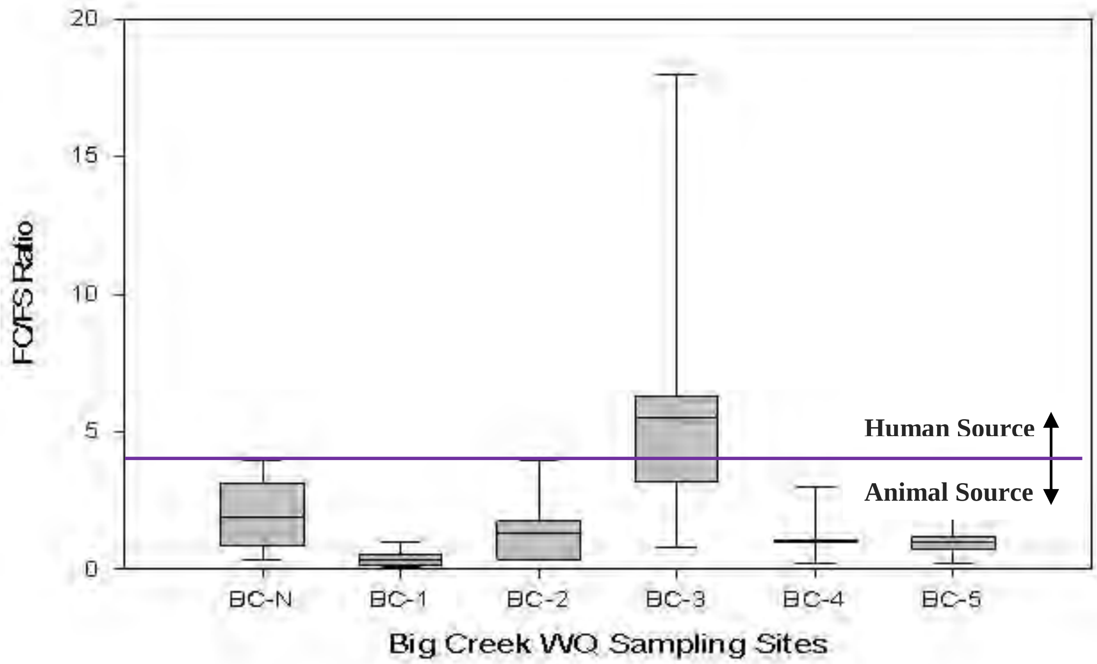


Table 4.10: Summary of Microbial Parameters in the Big Creek Watershed Study Area (Sept 2009 to Nov 2009)

Sampling Location	E.coli (EC)		Total coliform (TC)		Fecal coliform (FC)		Fecal Streptococci (FS)		Mean FC/FS Ratio
	Min	Max	Min	Max	Min	Max	Min	Max	
BC- N	50	350	250	4,050	50	650	50	750	1.91
BC - 1	50	100	950	5,100	50	150	100	750	0.39
BC - 2	100	500	350	4,850	50	650	50	500	1.36
BC - 3	150	3,800	1050	12,700	200	3,600	50	500	6.03
BC - 4	20	100	20	520	20	100	20	100	1.15
BC - 5	20	300	20	800	20	650	50	500	1.07
Lake - Up	20	50	20	1,900	20	200	20	50	1.50

Lake - Down	50	50	50	1,050	50	350	50	200	1.03

Biological Assessment of the Benthic Community

A multi-metric indices approach was used to assess the health of benthic (bottom dwelling) macroinvertebrates in the Big Creek watershed. Benthic sampling was conducted at six free flowing sites in the stream and two stagnant sites in the marsh area. Ten summary metrics (Table 4.5) were used to calculate the B-IBI value of each site.

The B-IBI scores for all the sites are summarized in Table 4.11. Based on two years of monitoring data, the benthic community is graded very poor to fair at the six monitoring sites in the tributary, while the two sites in the marsh show good benthic quality. Details about the findings at each sampling site are provided below.

Table 4.11: Summary of the B-IBI Scores in the Big Creek Watershed Study Area

Monitoring Site	B-IBI Score	Stream Condition
BC - N	11	Very Poor
BC - 1	30	Fair
BC - 2	20	Poor
BC - 3	21	Poor
BC - 4	30	Fair
BC - 5	32	Fair
Marsh – In	41	Good
Marsh - Down	43	Good

BC-N: The total taxa diversity at this site ranged from 11 to 13 total taxa and the number of relatively sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) ranged from three to five EPT during 2008-2009. The macroinvertebrates community was in poor condition. This site seemed to be impacted by low DO levels in combination with limited flow and the large drainage area with impervious cover.

BC-1: Sampling at this site produced a moderate diversity of macroinvertebrates fauna that was reflective of local stream habitat conditions. The macroinvertebrates community was in fair condition and was primarily affected by limited habitat. The total taxa diversity at this site ranged from 17 to 21 total taxa and the number of relatively sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) ranged six to seven EPT during 2008-2009.

BC-2 and BC-3: Both of these sites produced benthic assemblages reflective of a poor quality community condition. These sites lacked significant surface flow (observations by sampling crew) and appeared moderately enriched, as evidenced by excessive algal growth in the vicinity of the sampling sites. At both of these sites the stream bank appeared slumped and fine substrates were present in the sediment. The total taxa diversity at these sites ranged from 13 to 15 total taxa and the number of relatively sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) ranged from five to six EPT.

BC-4 and BC-5: These two sites supported fair macroinvertebrates communities that were typical of several other small streams in the Essex region. A relatively diverse macroinvertebrates assemblage was collected; however, pollution tolerant species predominated. The total taxa diversity at these sites ranged from 24 to 32 total taxa and the number of relatively sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) ranged six to seven EPT during 2008-2009. Relatively pollution sensitive taxa were well represented among the taxa collected and the communities were in fair conditions.

The Marsh Sites: The two sampling stations in the marsh area showed highly diverse macroinvertebrates assemblages. Based on the B-IBI scores, the communities were considered to be in good condition. The total taxa diversity at these sites ranged from 34 to 36 total taxa and the number of relatively sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) ranged from seven to nine EPT during 2008-2009. Eleven pollution tolerant taxa were collected at these sites and the community was predominated by snails. The water quality at these sites did not appear to be enriched and the communities appeared to be in good condition.

Overall Surface Water Quality

The following table summarizes the ranges of concentrations of various pollutants observed in the past as well as during the current monitoring study. The water quality standards and guidelines (benchmarks) are also tabulated in order to compare the concentration profiles during each monitoring period.

Table 4.12: Summary of Overall Water Quality Trends/Changes in the Big Creek Watershed

Parameter	Water Quality Benchmark	Study/Monitoring Program[1]		
		PWQMN (1964-1970)	CURB (1989-90)	Current Study (2008-2009)
Total Phosphorus, μg/L	30 μg/L	240 (±21.5)	285 (±53.1)	184 (±22.9)
Nitrate, mg/L	2.93 mg/L	1.68 (±0.35)	6.4 (±2.2)	1.1 (±0.6)
Total Suspended Solids, mg/L	25 mg/L	96 (±11.6)	98 (±14.6)	42 (±16.1)
Chloride, mg/L	210 mg/L	320 (±32.8)[2]	198 (±35.5)	124 (±38.5)
E.coli, CFU/100mL[3]	100 CFU/100mL	NA	6200	202

[1]Average Concentrations (varied sample size); [2]Data for 1985; [3]Geometric Mean; NA-Data Not Available

Pollutant Loadings

Sediment and nutrient loadings were estimated using the AnnAGNPS model from the Water Quantity Report. Average daily mass flow of total sediment from the watershed for current water quality (2008-2009) of pollutant loading is 8.3 mg/day; highest during April to June, likely caused by spring runoff

Average daily mass flow of N and P from the watershed are 207 kg/day and 112 kg/day, respectively; highest during March to May, likely caused by spring runoff. The lowest avgerage annual P and N yields occur in areas of forest and open water; while the highest occurs in agricultural areas.

4.3 Environmental Impacts, Opportunities, and Conclusions

Long term and current water quality data indicates a continuation of P, chloride and E. coli contamination, as well as poor benthic organism quality within the inland tributaries of the Big Creek watershed. Algae blooms have been observed in warmer months in the tributaries. Atrazine, a pesticide commonly detected in surface waters in Ontario, is also present above the benchmark at most tributary sites and at the marsh inlet. Water quality in the creek is impacted by various land uses; in general, marsh and nearshore water quality is better than the creek water quality. The role of the marsh in terms of nutrient uptake and E.coli assimilation need to be further investigated.

The highest loading of sediments occurs during spring runoff. Presently tile drains outlet directly into receiving drains which is not the case in other parts of the province where header tiles are commonly used to slow and manage sub-surface drain release. The highest occurrence of nutrient runoff has been modeled to come from agricultural areas with the lowest occurrence of nutrient runoff from natural areas including forest and marsh.

High chloride levels have been noted at the sampling site BC-3, directly downstream of the Soda Ash Settling Basin. This is being closely monitored by the MOE. Chloride levels at the inland tributary sites are much higher than at the marsh and nearshore lake sites.

Sources of bacterial loadings have historically resulted from faulty septic systems. The Phase I CURB Study indicated that sources of fecal contamination were likely manure management practices in past practices and land uses. Intensive monitoring is required on the issue of E.coli contamination at BC-3. More advanced microbial source tracking (MST) methods should be employed to track down human fecal source in the drainage area.

Future water quality monitoring in the Big Creek watershed should include analysis of dissolved phosphorus, particulate phosphorus, and inorganic phosphorus in addition to total phosphorus. Relative concentrations of each form of phosphorus will help in understanding phosphorus contamination sources in the watershed.

Stream flows need to be measured on a continuous basis throughout the year at the appropriate sites in the Big Creek watershed. These measurements should be strengthened and validated by occasional manual flow measurements. More accurate rating curves should be developed for the flow monitoring sites in the watershed.

2010

Big Creek Watershed Plan
Natural Heritage Study

Essex Region Conservation Authority

Town of Amherstburg

11/16/2010

Study Methods

Study Team

Data collection and analysis for the Big Creek Watershed Plan Natural Heritage Study was performed by the following team of specialists:

Floral Inventories and Vegetation Community Mapping:

- Dan Lebedyk, ERCA *Conservation Biologist*
- Robert Davies, ERCA *Forestry Technician*
- Gerry Waldron, *Consulting Ecologist*
- Peggy Hurst, *Consulting Biologist*
- Additional field support provided by: Mike Nelson, ERCA *Restoration Biologist* and Paul Giroux, ERCA *Forester*

Faunal Inventories and Significant Wildlife Habitat Assessment:

- Dave Martin, *Consulting Faunal Specialist*
- Dean Ware, *Consulting Faunal Specialist*

Provincially Significant Wetland Evaluation:

- Erin Sanders, OMNR *Wetland Evaluation Technician*

GIS Technical Support, Analysis and Mapping:

- Tom Dufour, ERCA *Geomatics/GIS Technician*
- Roger Palmini, ERCA *GIS/Data Specialist*
- Jovana Ilic, ERCA *GIS Technical Assistant*

Species At Risk Data Submitted To:

- Melody Cairns, OMNR *Species at Risk Biologist*

Methodology

Based on extensive public consultation, landowner permission was obtained and approximately 1319 hectares (3259 acres) of natural area within the Big Creek watershed were inventoried as part of the study.

In the spring of 2009, field biologists undertook the initial biological inventories of each of the sites which included the determination of the spring flora and an examination of standing water for amphibian breeding. Throughout the remainder of the 2009 field season, the team of specialists undertook additional faunal surveys, including wildlife and amphibian inventories; completed the botanical inventories to document summer and autumn flowering species and woody vegetation (trees and shrubs); as well as complete vegetation community mapping. A complete floral and faunal inventory was produced for each of the sites documenting all rare species. The locations of significant species and any Species at Risk were recorded utilizing a hand-held Global Positioning System (GPS).

Since the 1950s, there has been substantial work done across Canada to develop a standardized, ecological approach to land-unit description and classification. In Ontario this integrated approach to surveying and classifying vegetation communities is called the Ecological Land Classification System (ELC). This classification scheme identifies recurring ecological land patterns on the landscape in order to reduce complex natural variation to a reasonable number of meaningful ecosystem units. Ontario has adopted this land classification approach. The intent of the provincial ELC program is to establish a comprehensive, consistent province-wide approach for ecosystem description, inventory and interpretation. During the 2009 field season, all sites were mapped according to the ELC System. Because the ELC System is in the process of being improved, revised and updated as a result of data collection and input from expert field ecologists, the classification of vegetation communities are in a period of transition. This study has attempted to utilize the original ELC for Southern Ontario – First Approximation, as well as the August 2008 version of the improved ELC System. All vegetation communities were classified based on both versions of the ELC. In addition, 2008 high resolution aerial photography, at a scale of 1:1000, was utilized in the field to delimit the boundaries of the different ELC vegetation communities.

Evaluation Criteria

The following ten criteria were utilized by the study team, in order to document and evaluate a site's natural heritage significance. The first five criteria are based directly on the significant natural heritage features defined by the Provincial Policy Statement (PPS).

Criterion No. 1 – Significant Wetland

Wetlands are areas which are seasonally or permanently covered by shallow water, as well as lands where the water table is close to or at the surface. In either case the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic plants or water tolerant plants. Provincially Significant Wetlands (PSWs) are wetlands which are identified, mapped and scored using a scientific point-based system known as the Ontario Wetland Evaluation System (OWES).

During the 2009 field season, sites were evaluated by certified wetland evaluators from the Ontario Ministry of Natural Resources (OMNR). As a result, the wetland evaluation file and the boundary of the Big Creek Marsh PSW were revised accordingly.

Sites are deemed to have fulfilled Criterion No. 1 if they contain lands which are inside the newly revised boundary of the PSW.

Criterion No. 2 – Significant Habitat of Endangered/Threatened Species

Endangered Species are defined as species facing imminent extinction or extirpation in Ontario. Threatened Species are defined as a species that is at risk of becoming endangered in Ontario if limiting factors are not reversed. The habitat for these species are defined as portions of natural areas that are necessary for the maintenance, survival, and/or the recovery of naturally occurring or reintroduced populations of endangered species or threatened species, and areas of occurrence that are occupied or habitually occupied by the species during all or any part(s) of its life cycle.

During the 2009 floral and faunal field surveys, occurrences of species which are currently listed as Endangered or Threatened under Ontario's *Endangered Species Act* (*ESA*) were documented. Where possible, point locations of single individuals or populations were recorded using a handheld Global Positioning System (GPS) and a digital photograph of the specimen was recorded. These point locations where then cross-referenced with the results from the Ecological Land Classification (ELC) vegetation community mapping.

While this information does not necessarily constitute complete identification of significant habitat of Endangered or Threatened species, it will provide information on the known occurrences of these species and information regarding the habitat type in which these species occurred. This will assist OMNR staff in determining the potential presence of significant habitat.

Sites are deemed to have fulfilled Criterion No. 2 if they contain at least one occurrence of an Endangered or Threatened species. For faunal species this includes species which were determined to be residents. Individual species, along with the ELC vegetation type, are reported here under Criterion 2. This reporting however is considered to be confidential information and will only be made available to the appropriate staff personnel at the OMNR.

Criterion No. 3 – Significant Woodland

Significant woodlands are ecologically important in terms of features such as species composition, age of trees and stand history; functionally important due to its contribution to the broader landscape because of its location, size or due to the amount of forest cover in the planning area; and economically important due to site quality, species composition, or past management history. Vegetation community mapping was utilized in order to identify potential woodland/forested polygons. Utilizing the Ecological Land Classification (ELC) System for Southern Ontario, polygons which were of the following community series were selected as potential significant woodlands: Treed Shoreline (SHT), Treed Sand Barren and Dune (SBT), Deciduous Woodland (WOD), Deciduous Forest (FOD), Treed Agriculture/Plantations (TAG), and Deciduous Swamp (SWD). These polygons were then analyzed with respect to their size, location and context within the watershed, vegetation type and rarity status.

Sites are deemed to have fulfilled Criterion No. 3 if they contain woodlands which have any of the following characteristics:

- 2 hectares in size or larger;
- presence of interior forest habitat more than 100 m from the edge;
- greater than 0.5 hectares in size located within 30 metres of fish habitat likely receiving ecological benefit; or
- greater than 0.5 hectares in size consisting of a vegetation community with a provincial ranking of S1, S2 or S3 (as ranked by the OMNR's Natural Heritage Information Centre (NHIC)).

Criterion No. 4 – Significant Wildlife Habitat

Significant Wildlife Habitat is defined as areas where plants, animals and other organisms live, and find adequate amounts of food, water, shelter and space needed to sustain their populations. Specific wildlife habitats of concern may include areas where species concentrate at a vulnerable point in their annual life cycle; and areas which are important to migratory or non-migratory species. Significant Wildlife Habitat was assessed by utilizing guidelines contained within the Natural Heritage Reference Manual.

The faunal experts who conducted the faunal part of the site inventories analyzed the findings and determined if the site contained any of the following criteria for Significant Wildlife Habitat:

- Colonial Bird Nesting Sites
- Waterfowl Stopover & Staging Areas
- Waterfowl Nesting
- Landbird Migratory Stopover Areas
- Raptor Winter Feeding & Roosting Areas
- Turkey Vulture Summer Roosting Areas
- Reptile Hibernacula
- Bullfrog Concentration Areas
- Migratory Butterfly Stopover Habitat
- Rare Vegetation Communities
- Area-Sensitive Species
- Amphibian Woodland Breeding Ponds
- Turtle Nesting Habitat
- Specialized Raptor Nesting Habitat
- Habitats of Species of Conservation Concern
- Animal Movement Corridors

Sites are deemed to have fulfilled Criterion No. 4 if they contain at least one significant occurrence of the above noted features.

Criterion No. 5 – Significant Valleyland

Valleylands are natural areas that occur in a valley or other landform depression that have water flowing through or standing for some period of the year. These features often link or border natural areas and provide ecological functions such as habitat (including refuge), corridor, or buffering from adjacent impacts. The Essex Region Conservation Authority (ERCA) has defined the boundary of the Big Creek Significant Valleyland by applying guidelines from the Natural Heritage Reference Manual. For well-defined valleys, the physical boundary is generally defined by the stable top-of-bank or the predicted top-of-bank. For a less well-defined valley or stream corridor, the physical boundary may be defined in a number of ways including the consideration of riparian vegetation, the flooding hazard limit, the meander belt or the highest general level of seasonal inundation. In general, the Significant Valleyland boundary is defined based on the following considerations:

- Prominence as a distinctive landform
- Degree of naturalness
- Ecological functions (habitat, linkages, etc.)
- Restoration potential
- Historical-cultural value

Sites are deemed to have fulfilled Criterion No. 5 if they contain lands which are inside the boundary of the Significant Valleyland as defined by ERCA.

Criterion No. 6 – Ecological Function

The ecological function of a site is the natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes. These may include biological and physical interactions. For this study, linkage, hydrological flow, ground water recharge, water retention and water purification are to be considered components determining ecological function.

Criterion No. 7 – Diversity

Areas may be considered diverse if they support many species and associations, and a heterogeneous physical structure. Areas of high diversity contain several types of natural communities and will often encompass a spectrum of topography, soil types, moisture regimes and structure. Structural diversity is created by multiple horizontal layers within the community, edge, and the presence of dead timbers both standing and fallen. The evaluation of a site's community structure and diversity was completed utilizing the information obtained from the Ecological Land Classification (ELC) vegetation community mapping. For each site, the total number of ELC vegetation types in each Community Series was determined. Sites were considered to have fulfilled Criterion No. 7 if they contain at least 2 – 5 ELC vegetation types in 2 ELC Community Series, or 6 – 10 ELC vegetation types in one ELC Community Series. Sites which exhibit high diversity are those which contain 6 – 10 ELC vegetation types in 2 Community Series, or >10 ELC vegetation types in one ELC Community Series. A site was described as having very high diversity if they contained >10 ELC vegetation types in 2 Community Series or had 3 or more Community Series documented on the site.

Sites are homogenous if all of the vegetation is of the same ELC vegetation type and the same ELC Community Series and relatively homogeneous if they contain 2 – 5 ELC vegetation types in one ELC Community Series. These conditions do not represent a diverse site.

Criterion No. 8 – Significant Species

The study team conducted full inventories of both flora and fauna. The species which were identified were then cross-referenced with the rarity rankings provided by the OMNR's Natural Heritage Information Centre (NHIC). An explanation of the rarity rankings is as follows:

Global Rank (GRank):

Global ranks are assigned by a consensus of the network of conservation data centres, scientific experts, and The Nature Conservancy to designate a rarity rank based on the range-wide status of a species, subspecies or variety.

The most important factors considered in assigning global (and provincial) ranks are the total number of known, extant sites world-wide, and the degree to which they are potentially or actively threatened with destruction. Other criteria include the number of known populations considered to be securely protected, the size of the various populations, and the ability of the taxon to persist at its known sites. The taxonomic distinctness of each taxon has also been considered. Hybrids, introduced species, and taxonomically dubious species, subspecies and varieties have not been included. Global Rank (GRank) is defined as follows:

G1: **Extremely rare**; usually 5 or fewer occurrences in the overall range or very few remaining individuals; or because of some factor(s) making it especially vulnerable to extinction.
G2: **Very rare**; usually between 5 and 20 occurrences in the overall range or with many individuals in fewer occurrences; or because of some factor(s) making it vulnerable to extinction.
G3: **Rare to uncommon**; usually between 20 and 100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.
G4: **Common**; usually more than 100 occurrences; usually not susceptible to immediate threats.
G5: **Very common**; demonstrably secure under present conditions.
GH: **Historic**; no records in the past 20 years.
GU: **Status uncertain**; often because of low search effort or cryptic nature of the species; more data needed.
GX: **Globally extinct**; no recent records despite specific searches.
GNR: **Unranked**; Global rank not yet assessed.
Q: Denotes that the taxonomic status of the species, subspecies, or variety is **questionable**.

COSEWIC Status:

Status assigned by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). COSEWIC Status is defined as follows:

END : **Endangered**; a wildlife species facing imminent extirpation or extinction.
THR: **Threatened**; a wildlife species likely to become endangered if limiting factors are not reversed.
SC: **Special Concern**; a wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
EXP: **Extirpated**; a wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
EXT: **Extinct**; a wildlife species that no longer exists.
NAR: **Not At Risk**; a wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
DD: **Data Deficient**; a wildlife species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction.

MNR Status:

The MNR or Species at Risk in Ontario (SARO) Status is assigned by the OMNR. MNR Status is defined as follows:

END-R: **Endangered Regulated**; a species facing imminent extinction or extirpation in Ontario which has been regulated under Ontario's Endangered Species Act (ESA).
END: **Endangered**; a species facing imminent extinction or extirpation in Ontario which is a candidate for regulation under Ontario's ESA.
THR: **Threatened**; a species that is at risk of becoming endangered in Ontario if limiting factors are not reversed.
SC: **Special Concern**; a species with characteristics that make it sensitive to human activities or natural events.
EXP: **Extirpated**; a species that no longer exists in the wild in Ontario but still occurs elsewhere.

EXT: **Extinct**; a species that no longer exists anywhere.
NAR: **Not at Risk**; a species that has been evaluated and found to be not at risk.
DD: **Data Deficient**; a species for which there is insufficient information for a provincial status recommendation.

Ontario Rank (SRank):

Ontario (or subnational or provincial) ranks are used by the Natural Heritage Information Centre to set protection priorities for rare species and natural communities. These ranks are not legal designations. Provincial ranks are assigned in a manner similar to that described for global ranks, but consider only those factors within the political boundaries of Ontario. By comparing the global and provincial ranks, the status, rarity, and the urgency of conservation needs can be ascertained. The NHIC evaluates provincial ranks on a continual basis and produces updated lists at least annually. Ontario Rank (SRank) is defined as follows:

SX: **Presumed Extirpated**; species or community is believed to be extirpated from the nation or state/province. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
SH: **Possibly Extirpated (Historical)**; species or community occurred historically in the nation or state/province, and there is some possibility that it may be rediscovered. Its presence may not have been verified in the past 20-40 years. A species or community could become NH or SH without such a 20-40 year delay if the only known occurrences in a nation or state/province were destroyed or if it had been extensively and unsuccessfully looked for. The NH or SH rank is reserved for species or communities for which some effort has been made to relocate occurrences, rather than simply using this status for all elements not known from verified extant occurrences.
S1: **Critically Imperiled**; critically imperiled in the nation or state/province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province.
S2: **Imperiled**; imperiled in the nation or state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province.
S3: **Vulnerable**; vulnerable in the nation or state/province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
S4: **Apparently Secure**; uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5: **Secure**; common, widespread, and abundant in the nation or state/province.
SNR: **Unranked**; nation or state/province conservation status not yet assessed.
SU: **Unrankable**; currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
SNA: **Not Applicable**; a conservation status rank is not applicable because the species is not a suitable target for conservation activities.
S#S#: **Range Rank**; a numeric range rank (e.g., S2S3) is used to indicate any range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4).
S#B: **Breeding migrants**; there is no major concentration or staging areas during migration or in the non-breeding season.

S#N: **Non-breeding migrants**; for birds which have major concentration or staging areas during migration in the province.

Sites are deemed to have fulfilled Criterion No. 8 if they contain at least one occurrence of a species having a GRank of G1 to G3 or and SRank of S1 to S3.

Criterion No. 9 – Significant Communities

Significant communities contain an assemblage of plants and animals which are either unique or unusual in the local, provincial, or national context. These communities may be geographically isolated from other occurrences in the region or elsewhere in Ontario/Canada. All vegetation communities were identified and mapped according to the Ecological Land Classification (ELC) System for Southern Ontario (Lee et al., 1998; Lee, 2011). These communities were then cross-referenced with the rarity rankings provided by the OMNR's Natural Heritage Information Centre (NHIC). Any communities currently listed as S1 to S3 were considered a significant community. An explanation of the rarity rankings is as follows:

Global Rank (GRank):

Heritage Programs such as the NHIC use a combination of global and provincial ranks as a tool to prioritize conservation and protection efforts, focusing efforts first on those elements of diversity that are both globally and provincially rare. Global ranks for each element are assigned by The Nature Conservancy (United States), based upon consideration of the provincial and state ranks assigned by heritage programs for the element across the range of its distribution, as well as the opinion of scientific experts.

The two major criteria used in determining a community's rank are the total number of occurrences and the total areal extent of the community range-wide. Secondary factors used in determining global rank include measures of the geographic range of an element's distribution, trends in status (eg. expanding or shrinking range), trends in condition (eg. declining condition of remaining areal extent), threats, and fragility.

Until recently, global ranks were unavailable for community types, as there was no overall classification scheme that heritage programs could use to consistently classify vegetation according to similar standards. The Nature Conservancy (U.S.) has been working with the heritage programs to develop a standardized, hierarchical North American classification system appropriate for conservation planning and management, and for the long-term monitoring of ecological communities and ecosystems. Global ranks for this list were provided by The Nature Conservancy (TNC), Midwestern Regional Office, Minneapolis, Minnesota, in December 1996. Global ranks are defined as follows:

G1: Critically imperiled globally because of extreme rarity (5 or fewer occurrences or very few remaining hectares) or because of some factor(s) making it particularly vulnerable to extinction.

G2: Imperiled globally because of extreme rarity (6 to 20 occurrences or few remaining hectares) or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3: Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (eg. a single province or physiographic region) or because of other factor(s) making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 to 100.

Vegetation communities which are assigned lower ranks, such as G4 and G5, are considered to be globally secure. A rank of G4 refers to a community which is apparently secure globally, while a rank of G5 indicates a community is demonstrably secure globally.

Global ranks can be modified further, usually in cases where insufficient information exists for a community type. For example, G2G3 indicates that an element is rare, but it is not known if it is clearly G2 or G3. Since the global classification has only very recently been developed, and is based in some cases on incompletely documented community occurrences, in some cases there is uncertainty as to the validity or appropriateness of the global community type. In such cases, a rank of GQ may be applied. There are numerous information gaps for many communities, hence, a number of global types have insufficient information on which to properly determine rank. These have received an interim rank of G? until more information on the community becomes available.

Provincial Rank (SRank):

The NHIC uses a ranking system that considers the provincial rank of an element (=species or community type) as a tool to prioritize protection efforts. These ranks are not legal designations. The provincial (=subnational) rank is known as SRank. These ranks have been assigned using the best available scientific information, and follow a systematic ranking procedure developed by The Nature Conservancy (U.S.). The ranks are based on the three factors outlined in the three previous columns, namely: estimated number of occurrences, estimated community areal extent, and estimated range of the community within the province. The provincial ranks are explained below.

S1: Extremely rare in Ontario; usually 5 or fewer occurrences in the province, or very few remaining hectares.

S2: Very rare in Ontario; usually between 5 and 20 occurrences in the province, or few remaining hectares.

S3: Rare to uncommon in Ontario; usually between 20 and 100 occurrences in the province; may have fewer occurrences, but with some extensive examples remaining.

Communities which are assigned lower ranks, such as S4 and S5, are considered to be common and widespread in Ontario. A rank of S4 denotes a community that is apparently secure in the province, with many occurrences, while S5 indicates it is demonstrably secure in the province.

The provincial ranks may be further modified. For example, S2S3 indicates that an element is rare, but insufficient information exists to accurately assign a single rank. SH indicates that an element is known from the province historically, but that it hasn't been seen in many years, although it is not known conclusively to be extirpated. SX indicates that an element is extirpated from the province.

It is important to note that while only those communities which occur in southern Ontario are listed here, many of them occur elsewhere in the province. Consequently, these ranks are intended to reflect their total provincial extent and distribution.

Criterion No. 10 – Condition

A site considered to be in good condition should be relatively undisturbed by grazing, tillage, compaction, cutting and clearing, artificial drainage, stormwater flow, extraction, spraying of pesticides, trails, debris, and aggressive, introduced (exotic) species. If disturbed by one or more of the above, the area should have the potential to regenerate naturally or to be restored. Windthrow, disease and fire are considered to be natural disturbances which may be necessary to maintain the integrity of the ecosystem.

Life Science Areas of Natural and Scientific Interest (ANSIs) are areas of land and/or water containing natural landscapes or features which have been identified by the OMNR as significant representative segments of Ontario's biodiversity and natural landscapes including specific types of forests, valleys, prairies and wetlands, their native plants and animals and their supportive environments. They contain relatively undisturbed vegetation and landforms and their associated species and communities. Life Science ANSIs contain the best examples of particular landforms/vegetation features of a particular ecodistrict and are evaluated based on the following criteria: representation of landform-vegetation features of an ecodistrict; condition - an assessment of the degree of human-induced disturbances; diversity – the number of high quality, representative features that exist within a site; other ecological considerations – ecological and hydrological functions, connectivity, size, shape, proximity to other important areas, etc.; and special features such as populations of species at risk, special habitats, unusual life science features and educational or scientific value. Sites which are identified as within the Big Creek ANSI boundary are deemed to have fulfilled Criterion No. 10 due to being identified as one of the best examples of a shoreline marsh and associated wetland in the Province of Ontario.

In addition, every plant species at a particular site provides information relative to the quality of that site. Therefore, a Floristic Quality Analysis (FQA) was also applied to each site based on the full botanical inventory conducted during the 2009 field season. This was done by calculating a mean Coefficient of Conservatism (CC) and a Floristic Quality Index (FQI) from the comprehensive list of plant species obtain from the floral inventories. Generally, if the mean CC is above 3.5, the site is of sufficient floristic quality to be of remnant natural quality. If the mean CC is above 4.5, the site is considered to be a relatively intact natural area with high floristic quality. If the FQI has a value of 35 or more, one can be fairly confident that the site's flora is of sufficient quality to be of remnant natural quality and possess sufficient conservatism and richness to be floristically important from a Provincial perspective. An FQI below a value of 20 indicates that the site's flora is of minimal significance from a natural quality perspective. Any site which has an FQI exceeding 50 indicates that the site's flora is relatively intact with high floristic quality, an extremely rare condition representing a significant component of Ontario's native biodiversity and natural landscapes.

Relative Significance

The significance of a natural heritage area can be determined by assessing not only the number of evaluation criteria fulfilled, but also which of the 10 criteria were fulfilled.

As stated previously, the first five evaluation criteria are based on significance as defined by the Provincial Policy Statement (PPS). If a site fulfilled any one of these criteria, the site is considered significant with respect to the PPS. Sites which fulfill any of the PPS criteria for significance are considered to be more significant than those which fulfill some of the remaining criteria. In addition, it should be noted that sites that fulfill the criteria for Significant Wetland and Significant Habitat of Threatened and Endangered Species are considered to be more significant that those that satisfy the criteria for Significant Woodland, Significant Valleyland or Significant Wildlife Habitat. This is due to the fact that the PPS policies relating to Significant Wetlands and the Significant Habitat of Threatened and Endangered Species are prohibitive with respect to development and site alteration. This is in recognition of the importance and the sensitivity of these types of habitats in the landscape.

The assessment of relative significance between natural heritage areas also takes into account the sites location in the landscape (position relative to other natural heritage areas, and whether or not the site is linked or has the potential to be linked to other areas), size (larger areas generally have the capacity to exhibit higher biodiversity and be more stable than smaller areas), and vulnerability (the potential for the site to be lost due to existing land use or through future applications for development). By utilizing this suite of considerations, Administration is able to prioritize securement initiatives in order to conserve and protect the most significant and vulnerable sites.

Findings

General Characteristics

Area

The total area of all natural features surveyed during the 2009 field season was 1318.7 hectares (3258.5 acres). This represents approximately 85% of the entire natural area extent within the watershed which has been calculated to be 1560 hectares (3854 acres) (ERCA, 2013).

Soils

Upland soils within the watershed are mostly classified as Perth Clay (Pc), with some areas of Brookston Clay (Bc) in the southwest and northern portions of the watershed. In addition, Perth Clay Loam (Pcl) soils occur on the eastern side of the watershed and small areas of Burford Loam Shallow Phase (Bg-s) and Farmington Loam (Fl) occur in the northern portions of the watershed. The beach is classified as Eastport Sand (Es) and soils classified as Bottom Land (B.L.) occur mainly along the east branch of Big Creek. Wetland soils are classified as Marsh (Ma) and occur all along the Big Creek and Mans Marsh wetland areas.

Natural Heritage Significance

Lands within the watershed have been identified as within the Big Creek Marsh Provincially Significant Wetland (PSW), as a result of evaluation and mapping conducted by staff of the OMNR during the 2009 field season. The watershed contains the Big Creek Marsh life science Area of Natural and Scientific Interest (ANSI) as identified by the OMNR, signifying one of the best examples of shoreline marsh and associated wetland in the Province of Ontario. The watershed contains lands which are within the boundary of the Big Creek Significant Valleyland as mapped by the Essex Region Conservation Authority (ERCA). In addition, Big Creek has been identified as an Environmentally Significant Area (ESA) by ERCA, a Carolinian Canada Site and an Important Bird Area.

Ecological Function

The extensive wetland area within the watershed performs the ecological function of hydrological flow, water retention and purification; receiving water from upstream, and purifying it within the wetlands before flowing out into Lake Erie or filtering through the barrier beach. The main wetland area of the Big Creek marsh basin is the primary location where sediments settle out of suspension and nutrients and bacteria are metabolized by the extensive submergent aquatic wetland plant community. In addition, many portions of the watershed provide extensive linkage between the natural features at the mouth of Big Creek, along the Lake Erie shoreline, on Knapp's Island, and north of County Road 20.

Vegetation

Vegetation Communities

Diversity

The watershed exhibits extremely high diversity with respect to the number and types of vegetation communities, containing 115 ELC vegetation types (ecoelements) in 22 Community Series. Vegetation community composition is 63% wetland/aquatic and 37% terrestrial. The uplands support 53 woody and

13 herbaceous plant communities. The wetlands support 35 herbaceous and 14 woody plant communities. In addition, almost one quarter of the entire area surveyed is occupied by vegetation communities that are ranked as provincially rare; the most significant of these being the 214 hectare (529 acre) American Lotus Floating-leaved Shallow Aquatic vegetation community which occupies over 16% of the watershed area surveyed. The Big Creek watershed also contains the Region's largest (and perhaps only) stand of Wild Rice marsh, a community which requires fluctuating water levels in order to thrive.

The following is a summary of the ELC vegetation communities documented for the watershed:

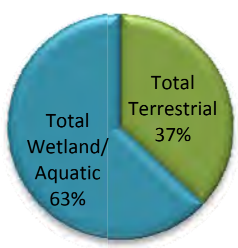
Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ac	Ha
Open Shoreline	Mineral Open Shoreline	SHOM1			10.81	4.37
	Reed-Canary Grass Mineral Open Shoreline	SHOM1-1			0.17	0.07
Shrub Shoreline	Mineral Shrub Shoreline	SHSM1			4.25	1.72
	Willow Mineral Shrub Shoreline	SHSM1-3			6.02	2.44
Treed Shoreline	Mineral Treed Shoreline	SHTM1			19.66	7.96
	Cottonwood Mineral Treed Shoreline	SHTM1-1			15.81	6.40
Shrub Sand Barren and Dune	Willow Shrub Sand Dune	SBSD1-3			0.55	0.22
Treed Sand Barren and Dune	Cottonwood Treed Sand Dune	SBTD1-1			2.12	0.86
Graminoid Meadow	Dry - Fresh Graminoid Tallgrass Prairie	MEGM1	G3	S1	2.77	1.12
	Fresh - Moist Graminoid Tallgrass Prairie	MEGM2-1	G2	S1	23.55	9.53
	Dry - Fresh Graminoid Meadow	MEGM3			3.31	1.34
	Reed Canary Grass Graminoid Meadow	MEGM3-8			0.48	0.19
	Fresh - Moist Graminoid Meadow	MEGM4			0.21	0.08
	Open Graminoid Meadow	MEGM4-1			3.40	1.38
Forb Meadow	Dry - Fresh Forb Meadow	MEFM1			4.50	1.82
	Goldenrod Forb Meadow	MEFM1-1			9.69	3.92
	Fresh - Moist Forb Meadow	MEFM4			12.93	5.23
Mixed Meadow	Dry - Fresh Mixed Meadow	MEMM3			0.36	0.14
	Fresh - Moist Mixed Meadow	MEMM4			38.03	15.39
Deciduous Thicket	Sumach Deciduous Shrub Thicket	THDM2-1			10.04	4.06
	Gray Dogwood Deciduous Shrub Thicket	THDM2-4			61.26	24.79
	Hawthorn Deciduous Shrub Thicket	THDM2-11			108.48	43.90
	Native Deciduous Regeneration Thicket	THDM4-1			30.38	12.30
	Fresh - Moist Deciduous Thicket	THDM5			141.39	57.22
	Gray Dogwood Deciduous Thicket	THDM5-1			215.77	87.32
	Poison Ivy Deciduous Thicket	THDM5-2			7.88	3.19
Deciduous Woodland	Dry Red Oak Woodland	WODM3-1			0.55	0.22
	Dry - Fresh Deciduous Woodland	WODM4			2.90	1.17
	Dry - Fresh Black Walnut Deciduous Woodland	WODM4-4			9.56	3.87
	Fresh - Moist Deciduous Woodland	WODM5			15.67	6.34
	Fresh - Moist Poplar Deciduous Woodland	WODM5-1			17.59	7.12
	Fresh - Moist Elm Deciduous Woodland	WODM5-2			9.62	3.89
	Fresh - Moist Manitoba Maple Deciduous Woodland	WODM5-3			2.12	0.86
	Fresh - Moist Hawthorn / Apple Deciduous Woodland	WODM5-4			10.30	4.17
Deciduous Forest	Dry - Fresh Oak - Hickory Deciduous Forest	FODM2-2	G4?	S3S4	87.32	35.34

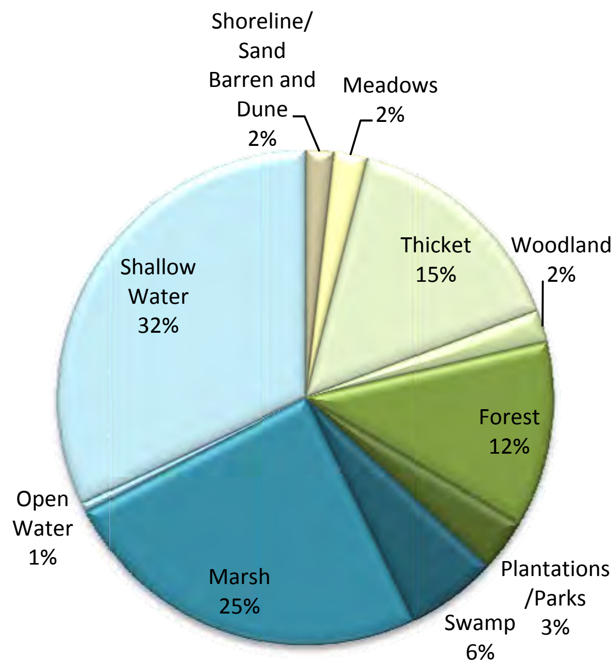
Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ac	Ha
	Dry - Fresh Hickory Deciduous Forest	FODM2-3	G4?	S3S4	9.71	3.93
	Dry - Fresh Hackberry Deciduous Forest	FODM4-3	G?	S2	21.08	8.53
	Dry - Fresh Black Locust Deciduous Forest	FODM4-11			0.59	0.24
	Fresh - Moist Lowland Deciduous Forest	FODM7			3.13	1.27
	Fresh - Moist White Elm Lowland Deciduous Forest	FODM7-1			1.87	0.76
	Fresh - Moist Green Ash - Hardwood Lowland Deciduous Forest	FODM7-2			0.90	0.36
	Fresh - Moist Willow Lowland Deciduous Forest	FODM7-3			4.85	1.96
	Fresh - Moist Black Walnut Lowland Deciduous Forest	FODM7-4	G4?	S2S3	60.13	24.33
	Fresh - Moist Manitoba Maple Lowland Deciduous Forest	FODM7-7			38.57	15.61
	Fresh - Moist Exotic Lowland Deciduous Forest	FODM7-9			0.22	0.09
	Fresh - Moist Cottonwood Deciduous Forest	FODM8-3			14.38	5.82
	Fresh - Moist Oak - Maple - Hickory Deciduous Forest	FODM9			42.93	17.37
	Fresh - Moist Oak - Maple Deciduous Forest	FODM9-2			19.11	7.73
	Fresh - Moist Bur Oak Deciduous Forest	FODM9-3			6.12	2.48
	Fresh - Moist Shagbark Hickory Deciduous Forest	FODM9-4			48.69	19.70
	Fresh - Moist Bitternut Hickory Deciduous Forest	FODM9-5			1.17	0.47
	Fresh - Moist Carolinian Deciduous Forest	FODM10			3.81	1.54
	Fresh - Moist Oak Carolinian Deciduous Forest	FODM10-2			9.92	4.02
	Naturalized Deciduous Hedge-row	FODM11			2.80	1.13
	Naturalized Deciduous Plantation	FODM12			28.80	11.65
Treed Agriculture	Coniferous Plantation	TAGM1			0.71	0.29
	Managed White Pine Coniferous Plantation	CUT_1-2			24.63	9.97
	Managed Austrian Pine Coniferous Plantation	CUT_1-12			4.15	1.68
	Managed White Spruce Coniferous Plantation	CUT_1-13			3.43	1.39
	Managed White Cedar Coniferous Plantation	CUT_1-16			2.22	0.90
	Mixed Plantation	TAGM2			17.62	7.13
	Deciduous Plantation	TAGM3			22.17	8.97
	Managed Silver Maple Deciduous Plantation	CUT_3-5			1.67	0.68
	Managed Green Ash Deciduous Plantation	CUT_3-7			18.18	7.36
	Fencerow	TAGM5			4.05	1.64
Green Lands	Parkland	CGL_2			25.59	10.36
Deciduous Swamp	Ash Mineral Deciduous Swamp	SWDM2			0.58	0.24
	Green Ash Mineral Deciduous Swamp	SWDM2-2			23.06	9.33
	Red Maple Mineral Deciduous Swamp	SWDM3-1			1.74	0.71
	Silver Maple Mineral Deciduous Swamp	SWDM3-2	G4?	S5	11.22	4.54
	Swamp Maple Mineral Deciduous Swamp	SWDM3-3			67.01	27.12
	Mineral Deciduous Swamp	SWDM4			6.55	2.65

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ac	Ha
	Willow Mineral Deciduous Swamp	SWDM4-1			20.64	8.35
	White Elm Mineral Deciduous Swamp	SWDM4-2	G?	S5	1.03	0.42
	White Birch - Cottonwood Deciduous Swamp	SWDM4-6			15.64	6.33
Thicket Swamp	Silky Dogwood Mineral Deciduous Thicket Swamp	SWTM2-2	G5	S3S4	1.25	0.50
	Gray Dogwood Mineral Deciduous Thicket Swamp	SWTM2-3	G5	S3S4	9.18	3.71
	Willow Mineral Deciduous Thicket Swamp	SWTM3	G5	S5	8.88	3.59
	Mixed Willow Mineral Deciduous Thicket Swamp	SWTM3-6			1.57	0.64
	Buttonbush Mineral Deciduous Thicket Swamp	SWTM5-1	G4	S3	41.31	16.72
Meadow Marsh	Canada Blue-joint Graminoid Mineral Meadow Marsh	MAMM1-1			14.48	5.86
	Cattail Graminoid Mineral Meadow Marsh	MAMM1-2			3.26	1.32
	Reed-canary Grass Graminoid Mineral Meadow Marsh	MAMM1-3			59.56	24.10
	Common Reed Graminoid Mineral Meadow Marsh	MAMM1-12			37.26	15.08
	Rice Cut-Grass Graminoid Mineral Meadow Marsh	MAMM1-14			0.26	0.10
	Mixed Graminoid Graminoid Mineral Meadow Marsh	MAMM1-16			14.42	5.84
	Forb Mineral Meadow Marsh	MAMM2	G?	S4S5	1.88	0.76
	Jewelweed Forb Mineral Meadow Marsh	MAMM2-1	G?	S4	1.47	0.60
	Mixed Mineral Meadow Marsh	MAMM3-1			3.90	1.58
Shallow Marsh	Graminoid Mineral Shallow Marsh	MASM1			4.08	1.65
	Cattail Mineral Shallow Marsh	MASM1-1	G5	S5	327.21	132.42
	Broad-leaved Sedge Mineral Shallow Marsh	MASM1-5	G4G5Q	S5	3.42	1.38
	Wild-rice Mineral Shallow Marsh	MASM1-6	G?	S5	11.82	4.78
	Bur-reed Mineral Shallow Marsh	MASM1-8	G4G5	S4	18.16	7.35
	Canada Blue-joint Graminoid Mineral Shallow Marsh	MASM1-9			1.79	0.73
	Rice Cut-grass Mineral Shallow Marsh	MASM1-10	G?	S4	2.76	1.12
	Common Reed Mineral Shallow Marsh	MASM1-12			266.47	107.84
	Reed Canary Grass Mineral Shallow Marsh	MASM1-14			6.66	2.70
	Forb Mineral Shallow Marsh	MASM2	G?	S4	21.52	8.71
	Forb Mineral Shallow Marsh	MASM2-1			32.41	13.12
	Purple Loosestrife Mineral Shallow Marsh	MASM2-4			6.40	2.59
	Water Willow Organic Shallow Marsh	MASO2-3	G?	S4	5.55	2.25
Open Aquatic	Open Aquatic	OAO			19.50	7.89
Shallow Aquatic	Shallow Water	SA			8.33	3.37
Submerged Shallow Aquatic	Pondweed Submerged Shallow Aquatic	SAS_1-1	G5Q	S5	3.13	1.27
	Coon-tail Submerged Shallow Aquatic	SAS_1-8			156.01	63.14
Mixed Shallow Aquatic	Mixed Shallow Aquatic	SAM_1			2.38	0.96
	Pickerel-weed Mixed Shallow Aquatic	SAM_1-1	G5	S5	9.29	3.76
	Duckweed Mixed Shallow Aquatic	SAM_1-2			247.86	100.30
	Pondweed Mixed Shallow Aquatic	SAM_1-4			22.92	9.28
	Bur-reed Mixed Shallow Aquatic	SAM_1-5	G5Q	S5	0.43	0.17
Floating-leaved Shallow Aquatic	Water Lily - Bullhead Lily Floating-leaved Shallow Aquatic	SAF_1-1	G5	S5	90.52	36.63
	American Lotus Floating-leaved Shallow Aquatic	SAF_1-2	G5	S1	528.63	213.93

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ac	Ha
	Duckweed Floating-leaved Shallow Aquatic	SAF_1-3			350.95	142.03
	Pondweed Floating-leaved Shallow Aquatic	SAF_1-4			0.25	0.10

Community Class	Hectares	Acres
Shoreline/Sand Barren and Dune	24.03	59.39
Meadows	28.85	71.28
Thicket	201.21	497.19
Woodland	27.33	67.53
Forest	159.75	394.74
Plantations/Parks	45.02	111.24
Swamp	79.23	195.77
Marsh	322.66	797.32
Open Water	7.89	19.50
Shallow Water	422.72	1044.56
Total Terrestrial	**486.18**	**1201.37**
Total Wetland/Aquatic	**832.50**	**2057.15**
Total Habitat	**1318.68**	**3258.52**





Significant Communities

The following 10 significant communities were identified and mapped according to the Ecological Land Classification (ELC) System for Southern Ontario (Lee et al., 1998; Lee, 2011). Global (GRank) and Provincial (SRank) rarity ranks for these vegetation communities are provided by the OMNR's Natural Heritage Information Centre (NHIC). Almost one quarter of the entire watershed area surveyed is occupied by vegetation communities that are ranked as provincially rare; the most significant of these being the 214 hectare (529 acre) American Lotus Floating-leaved Shallow Aquatic vegetation community which occupies over 16% of the watershed area surveyed. The Big Creek watershed may contain the largest population of this provincially rare plant and vegetation community in the entire Province of Ontario.

Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ac	Ha
Dry - Fresh Graminoid Tallgrass Prairie	MEGM1	G3	S1	2.77	1.12
Fresh - Moist Graminoid Tallgrass Prairie	MEGM2-1	G2	S1	23.55	9.53
Dry - Fresh Oak - Hickory Deciduous Forest	FODM2-2	G4?	S3S4	87.32	35.34
Dry - Fresh Hickory Deciduous Forest	FODM2-3	G4?	S3S4	9.71	3.93

Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ac	Ha
Dry - Fresh Hackberry Deciduous Forest	FODM4-3	G?	S2	21.08	8.53
Fresh - Moist Black Walnut Lowland Deciduous Forest	FODM7-4	G4?	S2S3	60.13	24.33
Silky Dogwood Mineral Deciduous Thicket Swamp	SWTM2-2	G5	S3S4	1.25	0.50
Gray Dogwood Mineral Deciduous Thicket Swamp	SWTM2-3	G5	S3S4	9.18	3.71
Buttonbush Mineral Deciduous Thicket Swamp	SWTM5-1	G4	S3	41.31	16.72
American Lotus Floating-leaved Shallow Aquatic	SAF_1-2	G5	S1	528.63	213.93
Total Area:				**784.9**	**317.6**

Significant Woodland

The Big Creek watershed contains woodlands which fulfill the Significant Woodland criterion, based on the following criteria:

- 2 hectares in size or larger,
- presence of interior forest habitat more than 100 m from the edge,
- greater than 0.5 hectares in size located within 30 metres of fish habitat likely receiving ecological benefit, and/or
- greater than 0.5 hectares in size consisting of a vegetation community with a provincial ranking of S1, S2 or S3 (as ranked by the OMNR's Natural Heritage Information Centre (NHIC)).

Within the study area there are no forest patches greater than 100 ha in size. The largest forest patch is part of Upper Big Creek Woods and is 82.4 ha in size. This includes Big Creek Site #51, 52, 54 & 55. In addition, 20 forest patches within the study area contain 100 m interior forest, of which 1 patch contains 200 m interior forest (ERCA, 2013).

Fifty-two (51) different wooded vegetation communities were identified throughout the watershed, with four (4) of these communities currently ranked as provincially rare:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ha	Ac
Treed Shoreline	Mineral Treed Shoreline	SHTM1			7.96	19.66
	Cottonwood Mineral Treed Shoreline	SHTM1-1			6.40	15.81
Treed Sand Barren and Dune	Cottonwood Treed Sand Dune	SBTD1-1			0.86	2.12
Deciduous Woodland	Dry Red Oak Woodland	WODM3-1			0.22	0.55
	Dry - Fresh Deciduous Woodland	WODM4			1.17	2.90
	Dry - Fresh Black Walnut Deciduous Woodland	WODM4-4			3.87	9.56
	Fresh - Moist Deciduous Woodland	WODM5			6.34	15.67
	Fresh - Moist Poplar Deciduous Woodland	WODM5-1			7.12	17.59
	Fresh - Moist Elm Deciduous Woodland	WODM5-2			3.89	9.62
	Fresh - Moist Manitoba Maple Deciduous Woodland	WODM5-3			0.86	2.12
	Fresh - Moist Hawthorn / Apple Deciduous Woodland	WODM5-4			4.17	10.30
Deciduous Forest	Dry - Fresh Oak - Hickory Deciduous Forest	FODM2-2	G4?	S3S4	35.34	87.32
	Dry - Fresh Hickory Deciduous Forest	FODM2-3	G4?	S3S4	3.93	9.71

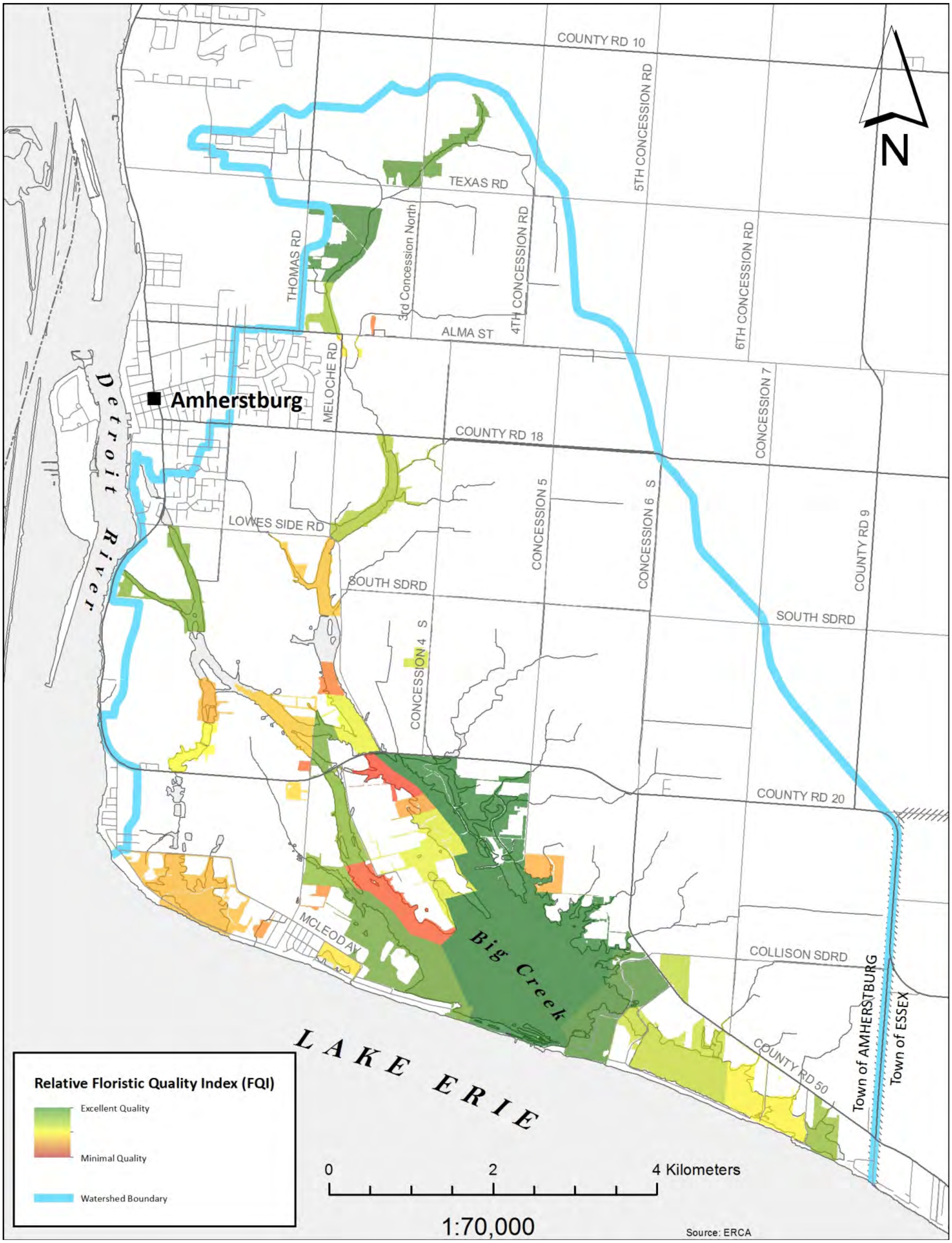
Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ha	Ac
	Dry - Fresh Hackberry Deciduous Forest	FODM4-3	G?	S2	8.53	21.08
	Dry - Fresh Black Locust Deciduous Forest	FODM4-11			0.24	0.59
	Fresh - Moist Lowland Deciduous Forest	FODM7			1.27	3.13
	Fresh - Moist White Elm Lowland Deciduous Forest	FODM7-1			0.76	1.87
	Fresh - Moist Green Ash - Hardwood Lowland Deciduous Forest	FODM7-2			0.36	0.90
	Fresh - Moist Willow Lowland Deciduous Forest	FODM7-3			1.96	4.85
	Fresh - Moist Black Walnut Lowland Deciduous Forest	FODM7-4	G4?	S2S3	24.33	60.13
	Fresh - Moist Manitoba Maple Lowland Deciduous Forest	FODM7-7			15.61	38.57
	Fresh - Moist Exotic Lowland Deciduous Forest	FODM7-9			0.09	0.22
	Fresh - Moist Cottonwood Deciduous Forest	FODM8-3			5.82	14.38
	Fresh - Moist Oak - Maple - Hickory Deciduous Forest	FODM9			17.37	42.93
	Fresh - Moist Oak - Maple Deciduous Forest	FODM9-2			7.73	19.11
	Fresh - Moist Bur Oak Deciduous Forest	FODM9-3			2.48	6.12
	Fresh - Moist Shagbark Hickory Deciduous Forest	FODM9-4			19.70	48.69
	Fresh - Moist Bitternut Hickory Deciduous Forest	FODM9-5			0.47	1.17
	Fresh - Moist Carolinian Deciduous Forest	FODM10			1.54	3.81
	Fresh - Moist Oak Carolinian Deciduous Forest	FODM10-2			4.02	9.92
	Naturalized Deciduous Hedge-row	FODM11			1.13	2.80
	Naturalized Deciduous Plantation	FODM12			11.65	28.80
Treed Agriculture	Coniferous Plantation	TAGM1			0.29	0.71
	Managed White Pine Coniferous Plantation	CUT_1-2			9.97	24.63
	Managed Austrian Pine Coniferous Plantation	CUT_1-12			1.68	4.15
	Managed White Spruce Coniferous Plantation	CUT_1-13			1.39	3.43
	Managed White Cedar Coniferous Plantation	CUT_1-16			0.90	2.22
	Mixed Plantation	TAGM2			7.13	17.62
	Deciduous Plantation	TAGM3			8.97	22.17
	Managed Silver Maple Deciduous Plantation	CUT_3-5			0.68	1.67
	Managed Green Ash Deciduous Plantation	CUT_3-7			7.36	18.18
	Fencerow	TAGM5			1.64	4.05
Deciduous Swamp	Ash Mineral Deciduous Swamp	SWDM2			0.24	0.58
	Green Ash Mineral Deciduous Swamp	SWDM2-2			9.33	23.06

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	GRank	SRank	Ha	Ac
	Red Maple Mineral Deciduous Swamp	SWDM3-1			0.71	1.74
	Silver Maple Mineral Deciduous Swamp	SWDM3-2	G4?	S5	4.54	11.22
	Swamp Maple Mineral Deciduous Swamp	SWDM3-3			27.12	67.01
	Mineral Deciduous Swamp	SWDM4			2.65	6.55
	Willow Mineral Deciduous Swamp	SWDM4-1			8.35	20.64
	White Elm Mineral Deciduous Swamp	SWDM4-2	G?	S5	0.42	1.03
	White Birch - Cottonwood Deciduous Swamp	SWDM4-6			6.33	15.64

Floral Species

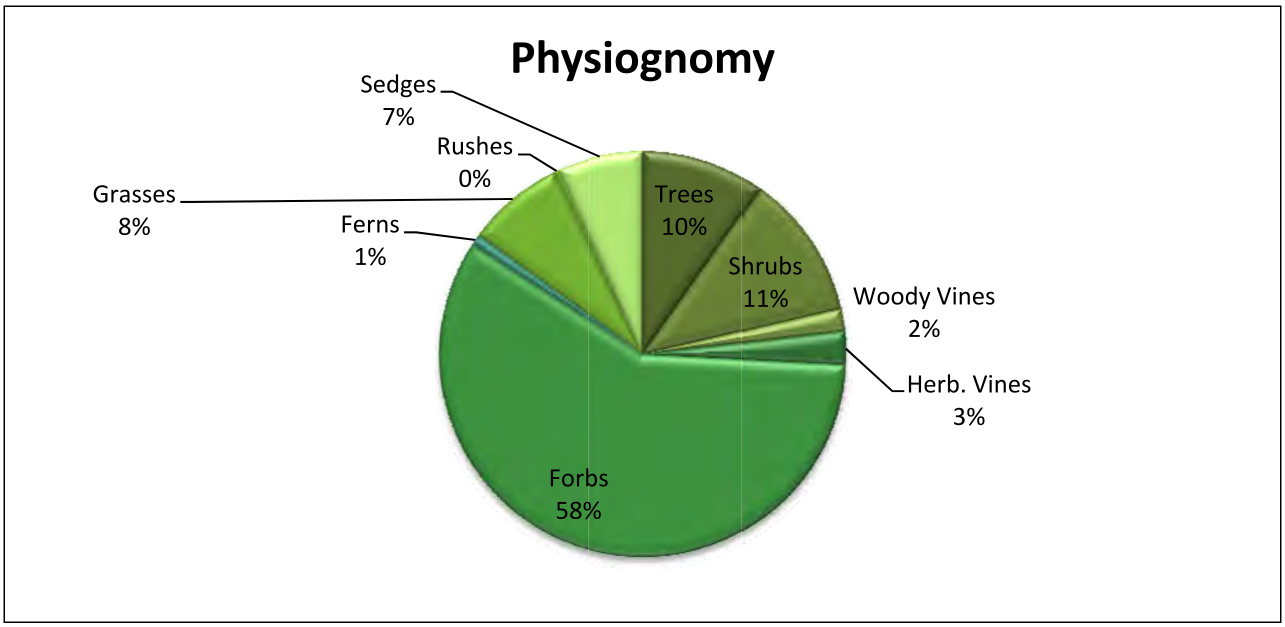
Floristically, the watershed's flora has a mean Coefficient of Conservatism (CC) of 5.10 and a Floristic Quality Index (FQI) value of 104.23. This indicates that the watershed's flora is relatively intact with high floristic quality, an extremely rare condition representing a significant component of Ontario's native biodiversity and natural landscapes. The following table and map depicts the relative significance of the study sites with respect to their FQI values.

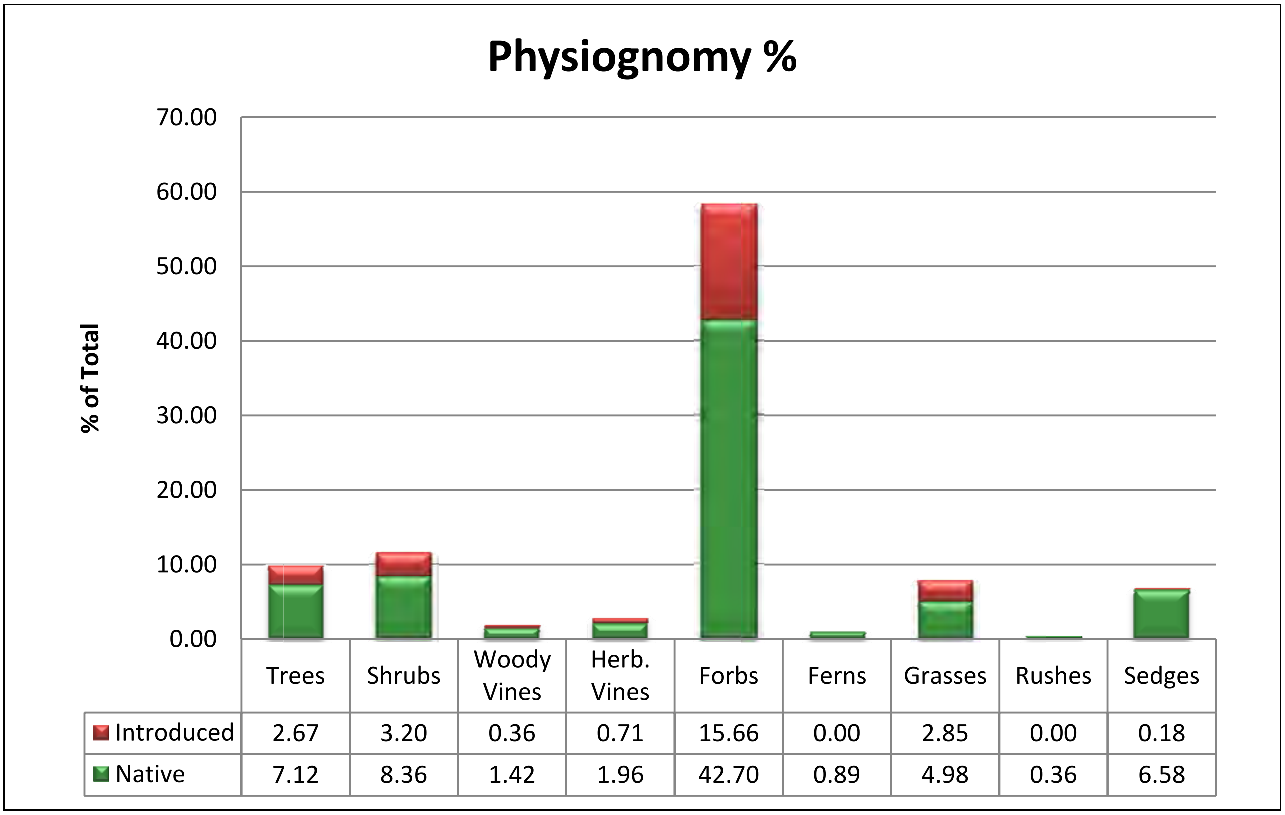
Site Number	FQI	Significance
6 & 13	67.73	Extremely rare and represent a significant component of Ontario's native biodiversity and natural landscapes.
52	61.94	
4	54.46	
54	53.47	
55	49.09	Possess sufficient conservatism and richness to be floristically important from a Provincial perspective.
15	47.91	
33	46.07	
41	45.61	
19	45.57	
1	44.99	
51	44.73	
46	44.28	
5	42.75	
3	42.71	
40	41.25	
9 & 10	40.31	
34	39.61	
27	38.99	
2	38.89	
49	38.88	
16	38.24	
21	38.16	
30 & 31	37.85	
44	37.46	
23	36.07	
28	33.11	
8	33.08	
11	32.79	
22	32.62	
18	28.55	
39	28.11	
50	23.06	
32	21.62	
17	19.15	Minimal significance from a natural quality perspective.
12	9.64	


COUNTY RD 10
5TH CONCESSION RD
N
TEXAS RD
3rd Concession North
4TH CONCESSION RD
6TH CONCESSION RD
THOMAS RD
ALMA ST
MELOCHE RD
Amherstburg
Detroit River
COUNTY RD 18
CONCESSION 7
CONCESSION 5
CONCESSION 6 S
COUNTY RD 9
LOWES SIDE RD
SOUTH SDRD
SOUTH SDRD
CONCESSION 4 S
COUNTY RD 20
MCLEOD AV
Big Creek
COLLISON SDRD
Town of AMHERSTBURG
Town of ESSEX
COUNTY RD 50
LAKE ERIE
Relative Floristic Quality Index (FQI)
Excellent Quality
Minimal Quality
Watershed Boundary
0
2
4 Kilometers
1:70,000
Source: ERCA

The Wetness Index for the watershed, calculated from the mean Coefficient of Wetness (CW) of all native taxa recorded from the site inventory, is -0.36 indicating that the site has a predominance of wetland species.

Floristic Quality Data	Native		Introduced		Species	
Species Type	**Number**	**% of Total**	**Number**	**% of Total**	**Number**	**% of Total**
Trees	40	7.12	15	2.67	55	9.79
Shrubs	47	8.36	18	3.20	65	11.57
Woody Vines	8	1.42	2	0.36	10	1.78
Total Woody	95	16.90	35	6.23	130	23.13
Herbaceous Vines	11	1.96	4	0.71	15	2.67
Forbs	240	42.70	88	15.66	328	58.36
Ferns	5	0.89	0	0.00	5	0.89
Total Herbaceous Non-Graminoids	256	45.55	92	16.37	348	61.92
Grasses	28	4.98	16	2.85	44	7.83
Rushes	2	0.36	0	0.00	2	0.36
Sedges	37	6.58	1	0.18	38	6.76
Total Graminoids	67	11.92	17	3.02	84	14.95
Total Non-Woody	323	57.47	109	19.40	432	76.87
Total All Species	418	74.38	144	25.62	562	100.00





Floral Inventory

A total of 562 plant species were identified from 4458 observations recorded during the botanical inventory for the watershed.

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Abutilon theophrasti	Velvet-leaf	G?			SE5	I
Acalypha virginica var. rhomboidea	Three-seeded Mercury	G5TE			S5	N
Acer negundo	Manitoba Maple	G5			S5	N
Acer platanoides	Norway Maple	G?			SE5	I
Acer pseudo-platanus	Sycamore Maple	G?			SE1	I
Acer rubrum	Red Maple	G5			S5	N
Acer saccharinum	Silver Maple	G5			S5	N
Acer saccharum ssp. saccharum	Sugar Maple	G5T?			S5	N
Acer x freemanii	Freeman's Maple	G?			S5	N
Achillea millefolium ssp. millefolium	Common Yarrow	G5T?			SE?	I
Actaea pachypoda	White Baneberry	G5			S5	N
Actaea rubra	Red Baneberry	G5			S5	N
Agalinis purpurea	Large-purple False Foxglove	G5			S1	N
Agalinis tenuifolia var. tenuifolia	Slender-leaved Agalinis	G5T?			SU	N
Agastache nepetoides	Yellow Giant Hyssop	G5			S4	N
Agrimonia gryposepala	Tall Hairy Agrimony	G5			S5	N
Agrimonia parviflora	Small-flower Agrimony	G5			S4	N
Agrimonia pubescens	Soft Agrimony	G5			S4	N
Agrostis gigantea	Redtop	G4G5			SE5	I

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Agrostis stolonifera	Spreading Bentgrass	G5			S5	N
Ailanthus altissima	Tree-of-heaven	G?			SE5	I
Alisma plantago-aquatica	Broad-leaved Water-plantain	G5			S5	N
Alliaria petiolata	Garlic Mustard	G?			SE5	I
Allium canadense var. canadense	Wild Garlic	G5T			S5	N
Allium cernuum	Nodding Wild Onion	G5			S2	N
Alnus glutinosa	European Black Alder	G?			SE4	I
Amaranthus powellii	Green Amaranth	G5			SE5	I
Amaranthus retroflexus	Red-root Amaranth	G?			SE5	I
Amaranthus tuberculatus	Rough-fruit Amaranth	G4G5			S4	N
Ambrosia artemisiifolia	Annual Ragweed	G5			S5	N
Ambrosia trifida	Great Ragweed	G5			S5	N
Amelanchier arborea	Downy Serviceberry	G5			S5	N
Ammophila breviligulata	Beach Grass	G5			S4	N
Amphicarpaea bracteata	Hog-peanut	G5			S5	N
Anagallis arvensis	Scarlet Pimpernel	G?			SE4	I
Andropogon gerardii	Big Bluestem	G5			S4	N
Anemone canadensis	Canada Anemone	G5			S5	N
Anemone quinquefolia var. quinquefolia	Wood Anemone	G5			S5	N
Anemone virginiana var. virginiana	Virginia Anemone	G5T			S5	N
Antennaria parlinii ssp. fallax	Hairy Pussytoes	G4G5T?			S5	N
Apios americana	American Groundnut	G5			S5	N
Apocynum cannabinum var. cannabinum	Clasping-leaf Dogbane	G5T			S5	N
Arctium lappa	Greater Burdock	G?			SE5	I
Arctium minus ssp. minus	Lesser Burdock	G?T?			SE5	I
Arisaema dracontium	Green Dragon	G5	SC	SC	S3	N
Arisaema triphyllum ssp. triphyllum	Jack-in-the-pulpit	G5T5			S5	N
Asarum canadense	Wild Ginger	G5			S5	N
Asclepias incarnata ssp. incarnata	Swamp Milkweed	G5T5			S5	N
Asclepias syriaca	Common Milkweed	G5			S5	N
Asclepias tuberosa	Butterfly Milkweed	G5			S4	N
Asparagus officinalis	Asparagus	G5?			SE5	I
Aster dumosus var. strictior	Bushy Aster	G5T4			S2	N
Aster ericoides ssp. ericoides	Heath Aster	G5T?			S5	N
Aster laevis var. laevis	Smooth Blue Aster	G5T?			S5	N
Aster lanceolatus ssp. lanceolatus	Panicled Aster	G5T?			S5	N
Aster lateriflorus var. lateriflorus	Calico Aster	G5T5			S5	N
Aster macrophyllus	Large-leaved Aster	G5			S5	N
Aster novae-angliae	New England Aster	G5			S5	N
Aster pilosus var. pilosus	Hairy Aster	G5T?			S5	N
Aster praealtus var. praealtus	Willow Aster	G5T5?	THR	THR	S2	N
Aster urophyllus	Arrow-leaved Aster	G4			S4	N
Atriplex patula	Halberd-leaf Saltbush	G5			S5	N
Barbarea verna	Early Yellow Rocket					I
Barbarea vulgaris	Yellow Rocket	G?			SE5	I

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Berberis thunbergii	Japanese Barberry	G?			SE5	I
Bidens cernua	Nodding Beggar's Ticks	G5			S5	N
Bidens coronata	Tall Swamp Beggar's Ticks	G5			S2	N
Bidens frondosa	Devil's Beggar's Ticks	G5			S5	N
Bidens tripartita	European Beggar's Ticks	G5			S5	N
Bidens vulgata	Tall Beggar's Ticks	G5			S5	N
Boehmeria cylindrica	False Nettle	G5			S5	N
Brassica nigra	Black Mustard	G?			SE5	I
Bromus inermis ssp. inermis	Smooth Brome	G4G5T?			SE5	I
Butomus umbellatus	Flowering-rush	G5			SE5	I
Cakile edentula	American Sea-rocket	G5T			S4	N
Calamagrostis canadensis	Blue-joint Reedgrass	G5			S5	N
Calla palustris	Wild Calla	G5			S5	N
Calystegia sepium ssp. americanum	Hedge Bindweed	G4G5T?			SU	N
Campanula americana	Tall Bellflower	G5			S4	N
Campsis radicans	Trumpet Creeper	G5			S2?	N
Capsella bursa-pastoris	Common Shepherd's Purse	G?			SE5	I
Cardamine bulbosa	Bulbous Bitter-cress	G5			S4	N
Cardamine concatenata	Cutleaf Toothwort	G5			S5	N
Cardamine pensylvanica	Pennsylvania Bitter-cress	G5			S5	N
Carex alopecoidea	Foxtail Sedge	G5			S5	N
Carex amphibola	Narrowleaf Sedge	G5			S2	N
Carex bebbii	Bebb's Sedge	G5			S5	N
Carex blanda	Woodland Sedge	G5?			S5	N
Carex cephalophora	Oval-leaved Sedge	G5			S5	N
Carex comosa	Bristly Sedge	G5			S5	N
Carex cristatella	Crested Sedge	G5			S5	N
Carex frankii	Frank's Sedge	G5			S2	N
Carex granularis	Meadow Sedge	G5			S5	N
Carex grayi	Asa Gray Sedge	G4			S4	N
Carex grisea	Narrow-leaved Sedge	G?			S4	N
Carex hirtifolia	Pubescent Sedge	G5			S5	N
Carex hyalinolepis	Shore-line Sedge	G4G5			S4	N
Carex hystericina	Porcupine Sedge	G5			S5	N
Carex lacustris	Lake-bank Sedge	G5			S5	N
Carex lupulina	Hop Sedge	G5			S5	N
Carex molesta	Troublesome Sedge	G4			S4?	N
Carex muskingumensis	Muskingum Sedge	G4			S3	N
Carex normalis	Larger Straw Sedge	G5			S4	N
Carex pellita	Woolly Sedge	G5			S5	N
Carex radiata	Stellate Sedge	G4			S5	N
Carex rosea	Rosy Sedge	G5			S5	N
Carex spicata	Spiked Sedge	G?			SE5	I
Carex squarrosa	Squarrose Sedge	G4G5			S2	N
Carex stipata	Stalk-grain Sedge	G5			S5	N
Carex stricta	Tussock Sedge	G5			S5	N
Carex tenera	Slender Sedge	G5T			S5	N

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Carex tribuloides	Blunt Broom Sedge	G5			S4S5	N
Carex vulpinoidea	Fox Sedge	G5			S5	N
Carpinus caroliniana ssp. virginiana	American Hornbeam	G5T			S5	N
Carya cordiformis	Bitternut Hickory	G5			S5	N
Carya glabra	Pignut Hickory	G5			S3	N
Carya laciniosa	Big Shellbark Hickory	G5			S3	N
Carya ovata var. ovata	Shagbark Hickory	G5			S5	N
Catalpa bignonioides	Southern Catalpa	G4G5			SE1	I
Celastrus scandens	Climbing Bittersweet	G5			S5	N
Celtis occidentalis	Common Hackberry	G5			S4	N
Cenchrus longispinus	Long-spine Sandbur	G5			S4	N
Centaurea maculosa	Spotted Knapweed	G?			SE5	I
Centaurium pulchellum	Branching Centaury-plant	G?			SE3	I
Cephalanthus occidentalis	Buttonbush	G5			S5	N
Cerastium arvense ssp. strictum	Field Chickweed	G5T?			S4	N
Cerastium fontanum	Common Mouse-ear Chickweed	G?			SE5	I
Cerastium nutans	Nodding Chickweed	G5			S4	N
Ceratophyllum demersum	Common Hornwort	G5			S5	N
Chamaesyce polygonifolia	Seaside Spurge	G5?			S4	N
Chelone glabra	Turtlehead	G5			S5	N
Chenopodium album var. album	White Goosefoot	G5T5			SE5	I
Chionodoxa forbesii	Glory Of The Snow					I
Chrysanthemum leucanthemum	Oxeye Daisy	G?			SE5	I
Cichorium intybus	Chicory	G?			SE5	I
Cicuta bulbifera	Bulb-bearing Water-hemlock	G5			S5	N
Cicuta maculata	Spotted Water-hemlock	G5			S5	N
Cinna arundinacea	Stout Wood Reedgrass	G5			S4	N
Circaea lutetiana ssp. canadensis	Enchanter's Nightshade	G5T5			S5	N
Cirsium arvense	Crepping Thistle	G?			SE5	I
Cirsium discolor	Field Thistle	G5			S3	N
Cirsium vulgare	Bull Thistle	G5			SE5	I
Claytonia virginica	Narrow-leaved Spring Beauty	G5			S5	N
Clematis virginiana	Virginia Virgin-bower	G5			S5	N
Clinopodium vulgare	Field Basil	G?			S5	N
Commelina communis	Asiatic Dayflower	G5			SE3	I
Convolvulus arvensis	Field Bindweed	G?			SE5	I
Conyza canadensis	Fleabane	G5			S5	N
Coreopsis lanceolata	Lance-leaved Coreopsis	G5			S4?	N
Coreopsis tripteris	Tall Coreopsis	G5			S2	N
Cornus amomum ssp. obliqua	Silky Dogwood	G5T?			S5	N
Cornus drummondii	Rough-leaved Dogwood	G5			S4	N
Cornus foemina ssp. racemosa	Gray Dogwood	G5			S5	N
Cornus stolonifera	Red-osier Dogwood	G5			S5	N
Coronilla varia	Crown-vetch	G?			SE5	I
Crataegus chrysocarpa	Fineberry Hawthorn	G5			S5	N

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Crataegus crus-galli	Cockspur Hawthorn	G5			S5	N
Crataegus dilatata	Eggert's Hawthorn	G4				N
Crataegus mollis	Downy Hawthorn	G5			S5	N
Crataegus pruinosa	Waxy-fruited Hawthorn	G5			S4?	N
Crataegus punctata	Dotted Hawthorn	G5			S5	N
Crataegus succulenta	Fleshy Hawthorn	G5			S4S5	N
Cryptotaenia canadensis	Canada Honewort	G5			S5	N
Cuscuta gronovii	Gronovius Dodder	G5			S5	N
Cyperus strigosus	Straw-colored Umbrella Sedge	G5			S5	N
Dactylis glomerata	Orchard Grass	G?			SE5	I
Danthonia spicata	Poverty Oat-grass	G5			S5	N
Datura stramonium	Jimson Weed	GU			SE5	I
Daucus carota	Queen Anne's Lace	G?			SE5	I
Decodon verticillatus	Hairy Swamp Loosestrife	G5			S5	N
Desmodium canadense	Showy Tick-trefoil	G5			S2	N
Desmodium paniculatum var. paniculatum	Panicled Tick-trefoil	G5T?			S4	N
Dioscorea quaternata	Fourleaf Wild-yam	G5			S4	N
Diplotaxis muralis	Stinking Wallrocket	G?			SE1	I
Diplotaxis tenuifolia	Slime-leaf Wallrocket	G?			SE5	I
Dipsacus fullonum ssp. sylvestris	Common Teasel	G?T?			SE5	I
Dryopteris carthusiana	Spinulose Wood Fern	G5			S5	N
Echinochloa crusgalli	Barnyard Grass	G?			SE5	I
Echinochloa walteri	Walter's Barnyard Grass	G5			S3	N
Echinocystis lobata	Wild Mock-cucumber	G5			S5	N
Elaeagnus angustifolia	Russian Olive	G?			SE3	I
Elaeagnus umbellata	Autumn Olive	G?			SE3	I
Eleocharis erythropoda	Bald Spikerush	G5			S5	N
Eleocharis smallii	Creeping Spikerush	G5?			S5	N
Elymus canadensis	Nodding Wild-rye	G5			S4S5	N
Elymus hystrix	Bottle-brush Grass	G5			S5	N
Elymus repens	Quack Grass	G?			SE5	I
Elymus villosus	Slender Wild-rye	G5			S4	N
Elymus virginicus var. virginicus	Virginia Wild-rye	G5T?			S5	N
Epilobium ciliatum ssp. ciliatum	Hairy Willow-herb	G5			S5	N
Epilobium coloratum	Purple-leaf Willow-herb	G5			S5	N
Epilobium hirsutum	Great-hairy Willow-herb	G?			SE5	I
Epipactis helleborine	Eastern Helleborine	G?			SE5	I
Equisetum arvense	Field Horsetail	G5			S5	N
Equisetum hyemale ssp. affine	Rough Horsetail	G5T5			S5	N
Equisetum laevigatum	Smooth Scouring-rush	G5			S4	N
Erigeron annuus	White-top Fleabane	G5			S5	N
Erigeron philadelphicus ssp. philadelphicus	Philadelphia Fleabane	G5T?			S5	N
Erigeron strigosus	Daisy Fleabane	G5			S5	N
Erythronium albidum	White Trout Lily	G5			S4	N
Erythronium americanum ssp. americanum	Yellow Trout-lily	G5T5			S5	N

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Euonymus atropurpurea var. atropurpurea	Burning Bush	G5			S3	N
Euonymus fortunei	Winter-creeper	G?			SE1	I
Euonymus obovata	Running Strawberry-bush	G5			S5	N
Eupatorium altissimum	Tall Boneset	G5			S1	N
Eupatorium maculatum ssp. maculatum	Spotted Joe-pye Weed	G5T5			S5	N
Eupatorium perfoliatum	Common Boneset	G5			S5	N
Eupatorium rugosum	White Snakeroot	G5			S5	N
Euphorbia dentata	Toothed Spurge	G5			SE4	I
Euthamia graminifolia	Grass-leaved Goldenrod	G5			S5	N
Euthamia gymnospermoides	Flat-topped Goldenrod	G5			S1	N
Festuca arundinacea	Kentucky Fescue	G?			SE5	I
Festuca rubra ssp. rubra	Red Fescue	G5T4			S5	I
Floerkea proserpinacoides	False Mermaid-weed	G5	NAR		S4	N
Fragaria vesca ssp. americana	Woodland Strawberry	G5T?			S5	N
Fragaria virginiana ssp. virginiana	Virginia Strawberry	G5T?			SU	N
Fraxinus americana	White Ash	G5			S5	N
Fraxinus nigra	Black Ash	G5			S5	N
Fraxinus pennsylvanica	Green Ash	G5			S5	N
Fraxinus profunda	Pumpkin Ash	G4			S2?	N
Galium aparine	Cleavers	G5			S5	N
Galium asprellum	Rough Bedstraw	G5			S5	N
Galium boreale	Northern Bedstraw	G5			S5	N
Galium circaezans	Wild Licorice	G5			S5	N
Galium lanceolatum	Torrey's Wild Licorice	G5			S5	N
Galium obtusum	Wild Madder	G5			S4S5	N
Galium palustre	Marsh Bedstraw	G5			S5	N
Galium triflorum	Sweet-scent Bedstraw	G5			S5	N
Galium verum	Yellow Bedstraw	G?			SE5	I
Gaura biennis	Biennial Gaura	G5			S3	N
Gentiana andrewsii	Closed Gentian	G4			S4	N
Geranium maculatum	Wild Geranium	G5			S5	N
Geranium robertianum	Herb-robert	G5			SE5	I
Geum aleppicum	Yellow Avens	G5			S5	N
Geum canadense	White Avens	G5			S5	N
Geum laciniatum	Rough Avens	G5			S4	N
Geum vernum	Spring Avens	G5			S4	N
Geum virginianum	Pale Avens	G5			SH	N
Glechoma hederacea	Ground Ivy	G?			SE5	I
Gleditsia triacanthos	Honey Locust	G5			S2	N
Glyceria striata	Fowl Manna Grass	G5			S5	N
Gymnocladus dioicus	Kentucky Coffee-tree	G5	THR	THR	S2	N
Hackelia virginiana	Virginia Stickseed	G5			S5	N
Helenium autumnale	Common Sneezeweed	G5			S5	N
Helianthus decapetalus	Thin-leaved Sunflower	G5			S5	N
Helianthus divaricatus	Woodland Sunflower	G5			S5	N
Helianthus giganteus	Tall Sunflower	G5			S5	N

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Helianthus tuberosus	Jerusalem Artichoke	G5			SE5	I
Heliopsis helianthoides	Ox-eye	G5			S5	N
Hemerocallis fulva	Orange Daylily	G?			SE5	I
Hesperis matronalis	Dame's Rocket	G4G5			SE5	I
Heuchera americana var. americana	Rock-geranium	G5			S2	N
Hibiscus moscheutos ssp. moscheutos	Swamp Rosemallow	G5	SC	SC	S3	N
Hieracium aurantiacum	Orange Hawkweed	G?			SE5	I
Hieracium caespitosum ssp. caespitosum	Field Hawkweed	G?			SE5	I
Hordeum jubatum ssp. jubatum	Fox-tail Barley	G5T?			SE5	I
Hydrastis canadensis	Golden Seal	G4	THR	THR	S2	N
Hydrocotyle americana	Common Frogbit	G?			SE5	I
Hydrophyllum virginianum	Virginia Waterleaf	G5			S5	N
Hypericum perforatum	St. John's-wort	G?			SE5	I
Hypericum punctatum	Common St. John's-wort	G5			S5	N
Impatiens capensis	Spotted Jewel-weed	G5			S5	N
Iris pseudacorus	Yellow Iris	G?			SE3	I
Iris virginica	Virginia Blue Flag	G5			S5	N
Juglans nigra	Black Walnut	G5			S4	N
Juncus tenuis	Slender Rush	G5			S5	N
Juncus torreyi	Torrey's Rush	G5			S5	N
Juniperus virginiana	Eastern Red Cedar	G5			S5	N
Lactuca biennis	Tall Blue Lettuce	G5			S5	N
Lactuca canadensis	Canada Lettuce	G5			S5	N
Lactuca floridana var. floridana	Woodland Lettuce	G5			S2	N
Lamium purpureum	Purple Deadnettle	G?			SE3	I
Laportea canadensis	Wood Nettle	G5			S5	N
Lathyrus latifolius	Everlasting Pea	G?			SE4	I
Leersia oryzoides	Rice Cutgrass	G5			S5	N
Leersia virginica	White Cutgrass	G5			S4	N
Lemna minor	Lesser Duckweed	G5			S5	N
Leonurus cardiaca ssp. cardiaca	Common Motherwort	G?T?			SE5	I
Lepidium campestre	Field Pepper-grass	G?			SE5	I
Leucospora multifida	Conobea	G5			S2	N
Ligustrum vulgare	European Privet	G?			SE5	I
Lindera benzoin	Spicebush	G5			S5	N
Lobelia cardinalis	Cardinal Flower	G5			S5	N
Lobelia inflata	Indian-tobacco	G5			S5	N
Lobelia siphilitica	Great Blue Lobelia	G5			S5	N
Lonicera dioica	Glaucous Honeysuckle	G5			S5	N
Lonicera japonica	Japanese Honeysuckle	G?			SE2	I
Lonicera maackii	Amur Honeysuckle	G?			SE2	I
Lonicera tatarica	Tartarian Honeysuckle	G?			SE5	I
Lotus corniculatus	Bird's-foot Trefoil	G?			SE5	I
Ludwigia palustris	Marsh Seedbox	G5			S5	N
Ludwigia polycarpa	Many-fruit False-loosestrife	G4			S2S3	N

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Lycopus americanus	American Bugleweed	G5			S5	N
Lycopus europaeus	European Bugleweed	G?			SE5	I
Lycopus rubellus	Taperleaf Bugleweed	G5			S3	N
Lycopus uniflorus	Northern Bugleweed	G5			S5	N
Lycopus virginicus	Virginia Bugleweed	G5			S3	N
Lysimachia ciliata	Fringed Loosestrife	G5			S5	N
Lysimachia nummularia	Moneywort	G?			SE5	I
Lythrum alatum	Winged Loosestrife	G5			S3	N
Lythrum salicaria	Slender-spike Loosestrife	G5			SE5	I
Maclura pomifera	Osage Orange	G2G4			SE2	I
Maianthemum canadense	Wild-lily-of-the-valley	G5			S5	N
Maianthemum racemosum ssp. racemosum	False Solomon's Seal	G5T			S5	N
Maianthemum stellatum	Starflower False Solomon's Seal	G5			S5	N
Malus baccata	Siberian Crabapple	G?			SE1	I
Malus coronaria	Sweet Crab-apple	G5			S4	N
Malus pumila	Common Apple	G5			SE5	I
Medicago lupulina	Black Medic	G?			SE5	I
Medicago sativa ssp. sativa	Alfalfa	G?T?			SE5	I
Melilotus alba	White Sweet Clover	G5			SE5	I
Melilotus officinalis	Yellow Sweet Clover	G?			SE5	I
Menispermum canadense	Canada Moonseed	G5			S4	N
Mentha arvensis ssp. borealis	Corn Mint	G5			S5	N
Mimulus ringens	Square-stem Monkey-flower	G5			S5	N
Mirabilis nyctaginea	Wild Four-o'clock	G5			S4	I
Miscanthus sacchariflorus	Japanese Silver Grass	G?			SE3	I
Miscanthus sinensis	Chinese Silver Grass	G?			SE1	I
Monarda fistulosa	Wild Bergamot	G5			S5	N
Morus alba	White Mulberry	G?			SE5	I
Morus rubra	Red Mulberry	G5	END	END	S2	N
Muhlenbergia frondosa	Leafy Satin Grass	G5			S4	N
Myosotis sylvatica	Woodland Forget-me-not	G5			SE4	I
Nelumbo lutea	American Lotus	G4			S2	N
Nepeta cataria	Catnip	G?			SE5	I
Nuphar advena	Yellow Pond-lily	G5			S3	N
Nymphaea odorata	Fragrant White Water-lily	G5			S5	N
Oenothera biennis	Common Evening-primrose	G5			S5	N
Oenothera parviflora	Northen Evening-primrose	G4?			S5?	N
Onoclea sensibilis	Sensitive Fern	G5			S5	N
Osmorhiza claytonii	Hairy Sweet-cicely	G5			S5	N
Osmorhiza longistylis	Smooth Sweet-cicely	G5			S5	N
Ostrya virginiana	Eastern Hop-hornbeam	G5			S5	N
Oxalis stricta	Upright Yellow Wood Sorrel	G5			S5	N
Panicum acuminatum var. acuminatum	Acuminate Panic Grass	G5T			S5	N

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Panicum dichotomiflorum	Spreading Panic Grass	G5			SE5	I
Panicum virgatum	Switch Grass	G5			S4	N
Parthenocissus inserta	Thicket Creeper	G5			S5	N
Parthenocissus quinquefolia	Virginia Creeper	G5			S4?	N
Pastinaca sativa	Wild Parsnip	G?			SE5	I
Penstemon hirsutus	Hairy Beardtongue	G4			S4	N
Penthorum sedoides	Ditch-stonecrop	G5			S5	N
Phalaris arundinacea	Reed Canary Grass	G5			S5	N
Phleum pratense	Timothy	G?			SE5	I
Phlox divaricata	Wild Blue Phlox	G5			S4	N
Phragmites australis	Common Reed	G5			S5	N
Phryma leptostachya	Lopseed	G5			S4S5	N
Phyla lanceolata	Fog Fruit	G5			S2	N
Physalis heterophylla	Clammy Ground-cherry	G5			S4	N
Physostegia virginiana ssp. virginiana	False Dragon-head	G5T?			S4	N
Phytolacca americana	Common Pokeweed	G5			S4	N
Picea abies	Norway Spruce	G?			SE3	I
Picea glauca	White Spruce	G5			S5	N
Pilea pumila	Canada Clearweed	G5			S5	N
Pinus nigra	Black Pine	G?			SE2	I
Pinus resinosa	Red Pine	G5			S5	N
Pinus strobus	Eastern White Pine	G5			S5	N
Pinus sylvestris	Scotch Pine	G?			SE5	I
Plantago lanceolata	English Plantain	G5			SE5	I
Plantago major	Nipple-seed Plantain	G5			SE5	I
Plantago rugelii	Black-seed Plantain	G5			S5	N
Platanus occidentalis	Sycamore	G5			S4	N
Poa annua	Annual Bluegrass	G?			SE5	I
Poa compressa	Canada Bluegrass	G?			S5	N
Poa pratensis ssp. pratensis	Kentucky Bluegrass	G5T			S5	N
Podophyllum peltatum	May Apple	G5			S5	N
Polanisia dodecandra	Common Clammy-weed	G5Q			S4	N
Polygala verticillata	Whorled Milkwort	G5			S4	N
Polygonatum biflorum	Giant Solomon's Seal	G5			S4	N
Polygonatum pubescens	Downy Solomon's Seal	G5			S5	N
Polygonum amphibium	Water Smartweed	G5			S5	N
Polygonum convolvulus	Black Bindweed	G?			SE5	I
Polygonum hydropiper	Water-pepper	G5			SE5	I
Polygonum hydropiperoides	Mild Water-pepper	G5			S5	N
Polygonum lapathifolium	Dock-leaf Smartweed	G5			S5	N
Polygonum pensylvanicum	Pennsylvania Smartweed	G5			S5	N
Polygonum persicaria	Lady's Thumb	G?			SE5	I
Polygonum punctatum	Dotted Smartweed	G5			S5	N
Polygonum sagittatum	Arrow-leaved Tearthumb	G5			S4	N
Polygonum scandens	Climbing False-buckwheat	G5			S4S5	N
Polygonum virginianum	Virginia Knotweed	G5			S4	N
Pontederia cordata	Pickerel Weed	G5			S5	N

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Populus deltoides ssp. deltoides	Eastern Cottonwood	G5T5			SU	N
Populus tremuloides	Quaking Aspen	G5			S5	N
Potamogeton crispus	Curly Pondweed	G5			SE5	I
Potamogeton natans	Floating Pondweed	G5			S5	N
Potentilla anserina ssp. anserina	Silverweed	G5			S5	N
Potentilla norvegica ssp. monspeliensis	Norwegian Cinquefoil	G5T?			S5	N
Potentilla recta	Sulphur Cinquefoil	G?			SE5	I
Potentilla simplex	Old-field Cinquefoil	G5			S5	N
Prenanthes alba	White Rattlesnake-root	G5			S5	N
Proserpinaca palustris	Marsh Mermaid-weed	G5			S4	N
Prunella vulgaris ssp. lanceolata	Self-heal	G5T?			S5	N
Prunus americana	American Plum	G5			S4	N
Prunus cerasus	Sour Red Cherry	G?			SE1	I
Prunus mahaleb	Perfumed Cherry	G5			SE2	I
Prunus nigra	Canada Plum	G4G5			S4	N
Prunus serotina	Wild Black Cherry	G5			S5	N
Prunus virginiana ssp. virginiana	Choke Cherry	G5T?			S5	N
Ptelea trifoliata	Hop Tree	G5	THR	THR	S3	N
Pycnanthemum virginianum	Virginia Mountain-mint	G5			S4	N
Pyrus communis	Common Pear	G5			SE4	I
Quercus alba	White Oak	G5			S5	N
Quercus bicolor	Swamp White Oak	G5			S4	N
Quercus macrocarpa	Bur Oak	G5			S5	N
Quercus muehlenbergii	Chinquapin Oak	G5			S4	N
Quercus palustris	Pin Oak	G5			S4	N
Quercus rubra	Northern Red Oak	G5			S5	N
Quercus shumardii	Shumard's Oak	G5	SC	SC	S3	N
Quercus velutina	Black Oak	G5			S4	N
Ranunculus abortivus	Kidney-leaved Buttercup	G5			S5	N
Ranunculus ficaria	Fig-root Buttercup	G?T?			SE1	I
Ranunculus hispidus var. hispidus	Bristly Buttercup	G5T5			S3	N
Ranunculus sceleratus var. sceleratus	Cursed Crowfoot	G5T5			S5	N
Ratibida pinnata	Gray-headed Coneflower	G5			S3	N
Rhamnus cathartica	Buckthorn	G?			SE5	I
Rhamnus frangula	Glossy Buckthorn	G?			SE5	I
Rhus aromatica	Fragrant Sumac	G5			S5	N
Rhus glabra	Smooth Sumac	G5			S5	N
Rhus radicans ssp. negundo	Poison Ivy	G5T			S5	N
Rhus radicans ssp. rydbergii	Western Poison Ivy	G5T			S5	N
Rhus typhina	Staghorn Sumac	G5			S5	N
Ribes americanum	Wild Black Currant	G5			S5	N
Ribes cynosbati	Prickly Gooseberry	G5			S5	N
Robinia pseudo-acacia	Black Locust	G5			SE5	I
Rorippa palustris ssp. fernaldiana	Bog Yellow-cress	G5T?			S5	N
Rosa canina	Dog Rose	G?			SE2	I
Rosa carolina	Carolina Rose	G4G5			S4	N

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Rosa multiflora	Rambler Rose	G?			SE4	I
Rosa palustris	Swamp Rose	G5			S5	N
Rosa setigera	Climbing Prairie Rose	G5	SC	SC	S3	N
Rubus allegheniensis	Allegheny Blackberry	G5			S5	N
Rubus flagellaris	Northern Dewberry	G5			S4	N
Rubus hispidus	Trailing Blackberry	G5			S4S5	N
Rubus occidentalis	Black Raspberry	G5			S5	N
Rudbeckia hirta	Black-eyed Susan	G5			S5	N
Rumex crispus	Curly Dock	G?			SE5	I
Rumex orbiculatus	Water Dock	G5			S4S5	N
Rumex verticillatus	Swamp Dock	G5			S4	N
Sagittaria latifolia	Broadleaf Arrowhead	G5			S5	N
Salix alba	White Willow	G5			SE4	I
Salix amygdaloides	Peach-leaved Willow	G5			S5	N
Salix bebbiana	Bebb's Willow	G5			S5	N
Salix discolor	Pussy Willow	G5			S5	N
Salix eriocephala	Heart-leaved Willow	G5			S5	N
Salix exigua	Sandbar Willow	G5			S5	N
Salix fragilis	Crack Willow	G?			SE5	I
Salix purpurea	Basket Willow	G5			SE4	I
Salix X pendulina	Hybrid Willow	HYB			SE1	I
Salsola kali	Russian Thistle	G?			SE5	I
Sambucus canadensis	Common Elderberry	G5			S5	N
Sanguinaria canadensis	Bloodroot	G5			S5	N
Sanicula canadensis var. canadensis	Short-styled Sanicle	G5T5			S4	N
Sanicula marilandica	Black Snakeroot	G5			S5	N
Sanicula odorata	Clustered Snakeroot	G5			S5	N
Sanicula trifoliata	Large-fruited Snakeroot	G4			S4	N
Saponaria officinalis	Bouncing-bet	G?			SE5	I
Schizachyrium scoparium	Little Bluestem	G5			S4	N
Scirpus acutus	Hard-stemmed Bulrush	G5			S5	N
Scirpus atrovirens	Woolgrass Bulrush	G5?			S5	N
Scirpus cyperinus	Cottongrass Bulrush	G5			S5	N
Scirpus fluviatilis	River Bulrush	G5			S4S5	N
Scirpus pendulus	Pendulous Bulrush	G5			S5	N
Scirpus validus	Soft-stemmed Bulrush	G?			S5	N
Scrophularia marilandica	Carpenter's Square Figwort	G5			S4	N
Scutellaria galericulata	Hooded Skullcap	G5			S5	N
Scutellaria lateriflora	Mad Dog Skullcap	G5			S5	N
Sedum telephium ssp. fabaria	Live Forever	G?T?			SE2	I
Senecio vulgaris	Old-man-in-the-spring	G?			SE5	I
Setaria faberi	Giant Foxtail	G?			SE4	I
Setaria pumila	Yellow Foxtail	G?			SE5	I
Setaria viridis	Green Bristle Grass	G?			SE5	I
Sicyos angulatus	One-seed Bur-cucumber	G5			S5	N
Silphium terebinthinaceum var. terebinthinaceum	Prairie Dock	G4G5T4T5			S1	N

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Sisymbrium altissimum	Tall Tumble Mustard	G?			SE5	I
Sisyrinchium albidum	White Blue-eyed Grass	G5?			S1	N
Sisyrinchium angustifolium	Pointed Blue-eyed-grass	G4?			S4	N
Sium suave	Hemlock Water-parsnip	G5			S5	N
Smilax ecirrhata	Upright Greenbrier	G5?			S3?	N
Smilax herbacea	Smooth Herbaceous Greenbrier	G5			S4	N
Smilax hispida	Hispid Greenbrier	G5Q			S4	N
Smilax illinoensis	Illinois Greenbrier	G4?			S2?	N
Smilax lasioneura	Herbaceous Greenbrier	G5			S4	N
Solanum dulcamara	Climbing Nightshade	G?			SE5	I
Solidago altissima var. altissima	Tall Goldenrod	G?			S5	N
Solidago canadensis	Canada Goldenrod	G5			S5	N
Solidago gigantea	Smooth Goldenrod	G5			S5	N
Solidago juncea	Early Goldenrod	G5			S5	N
Solidago nemoralis ssp. nemoralis	Field Goldenrod	G5T?			S5	N
Solidago riddellii	Riddell's Goldenrod	G5	SC	SC	S3	N
Solidago rigida ssp. rigida	Stiff Goldenrod	G5T5			S3	N
Solidago sempervirens	Seaside Goldenrod	G5			SE2	I
Sonchus arvensis ssp. arvensis	Field Sowthistle	G?T?			SE5	I
Sonchus arvensis ssp. uliginosus	Perennial Sowthistle	G?T?			SE5	I
Sonchus oleraceus	Common Sowthistle	G?			SE5	I
Sorghastrum nutans	Yellow Indian-grass	G5			S4	N
Sparganium americanum	American Bur-reed	G5			S4?	N
Sparganium eurycarpum	Large Bur-reed	G5			S5	N
Spartina pectinata	Fresh Water Cordgrass	G5			S4	N
Sphenopholis intermedia	Slender Wedge Grass	G5			S4S5	N
Spiraea alba	Narrow-leaved Meadow-sweet	G5			S5	N
Spiranthes magnicamporum	Great Plains Ladies'-tresses	G4			S3?	N
Stachys hispida	Hispid Hedge-nettle	G4Q			S4S5	N
Stachys palustris	Marsh Hedge-nettle	G5			SE5	I
Staphylea trifolia	American Bladdernut	G5			S4	N
Stellaria longifolia	Longleaf Stitchwort	G5			S5	N
Strophostyles helvola	Wild Bean	G5			S4	N
Symphoricarpos albus	Snowberry	G5			S5	N
Symphytum officinale ssp. officinale	Common Comfrey	G?			SE5	I
Taenidia integerrima	Yellow Pimpernell	G5			S4	N
Taraxacum officinale	Common Dandelion	G5			SE5	I
Teucrium canadense ssp. viscidum	Wood Germander	G5T4			SU	N
Thalictrum dasycarpum	Purple Meadowrue	G5			S4?	N
Thalictrum dioicum	Early Meadowrue	G5			S5	N
Thaspium trifoliatum var. aureum	Purple Meadow-parsnip	G5T5			S2	N
Thuja occidentalis	Northern White Cedar	G5			S5	N
Tilia americana	American Basswood	G5			S5	N
Tragopogon pratensis ssp. pratensis	Meadow Goat's-beard	G?T?			SE5	I
Trifolium hybridum ssp. elegans	Alsike Clover	G?			SE5	I
Trifolium pratense	Red Clover	G?			SE5	I

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Trifolium repens	White Clover	G?			SE5	I
Trillium grandiflorum	White Trillium	G5			S5	N
Triodanis perfoliata	Venus'-looking-glass	G5			S4	N
Triosteum aurantiacum	Horse Gentian	G5			S5	N
Triosteum perfoliatum	Perfoliate Horse Gentian	G5			S1	N
Triplasis purpurea	Purple Sandgrass	G4G5			S4?	N
Tussilago farfara	Colt's Foot	G?			SE5	I
Typha angustifolia	Narrow-leaved Cattail	G5			S5	N
Typha latifolia	Broad-leaf Cattail	G5			S5	N
Typha x glauca	Blue Cattail	HYB			S4?	N
Ulmus americana	American Elm	G5?			S5	N
Ulmus pumila	Siberian Elm	G?			SE3	I
Ulmus rubra	Slippery Elm	G5			S5	N
Urtica dioica ssp. dioica	Stinging Nettle	G5T?			SE2	I
Urtica dioica ssp. gracilis	Slender Stinging Nettle	G5T?			S5	N
Utricularia sp.	Bladderwort Species					N
Verbascum thapsus	Common Mullein	G?			SE5	I
Verbena hastata	Blue Vervain	G5			S5	N
Verbena urticifolia	White Vervain	G5			S5	N
Verbesina alternifolia	Wingstem	G5			S3	N
Vernonia gigantea ssp. gigantea	Giant Ironweed	G5			S1?	N
Vernonica missurica	Ironweed	G4G5			S3?	N
Veronica arvensis	Corn Speedwell	G?			SE5	I
Veronica peregrina ssp. peregrina	Purslane Speedwell	G5T?			S5	N
Veronica serpyllifolia ssp. serpyllifolia	Thyme-leaved Speedwell	G?T?			SE5	N
Veronicastrum virginicum	Culver's-root	G4			S2	N
Viburnum lentago	Nannyberry	G5			S5	N
Viburnum opulus	Guelder-rose Viburnum	G5			SE4	I
Viburnum rafinesquianum	Downy Arrow-wood	G5			S5	N
Viburnum trilobum	Highbush Cranberry	G5T5			S5	N
Vicia cracca	Tufted Vetch	G?			SE5	I
Viola affinis	Lecontes Violet	G5			S4?	N
Viola cucullata	Marsh Blue Violet	G4G5			S5	N
Viola nephrophylla	Northern Bog Violet	G5			S4	N
Viola pubescens	Downy Yellow Violet	G5			S5	N
Viola sororia	Woolly Blue Violet	G5			S5	N
Vitis riparia	Riverbank Grape	G5			S5	N
Wolffia columbiana	Columbia Watermeal	G5			S4S5	N
Xanthium strumarium	Rough Cockle-bur	G?			S5	N
Yucca filamentosa	Adam's Needle					I
Zanthoxylum americanum	Northern Prickly Ash	G5			S5	N
Zizania aquatica	Southern Wild Rice	G5			S3	N

Significant Flora

The following 56 significant floral species were documented in the Big Creek Watershed:

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Agalinis purpurea	Large-purple False Foxglove	G5			S1	N
Allium cernuum	Nodding Wild Onion	G5			S2	N
Arisaema dracontium	Green Dragon	G5	SC	SC	S3	N
Aster dumosus var. strictior	Bushy Aster	G5T4			S2	N
Aster praealtus var. praealtus	Willow Aster	G5T5?	THR	THR	S2	N
Bidens coronata	Tall Swamp Beggar's Ticks	G5			S2	N
Campsis radicans	Trumpet Creeper	G5			S2?	N
Carex amphibola	Narrowleaf Sedge	G5			S2	N
Carex frankii	Frank's Sedge	G5			S2	N
Carex muskingumensis	Muskingum Sedge	G4			S3	N
Carex squarrosa	Squarrose Sedge	G4G5			S2	N
Carya glabra	Pignut Hickory	G5			S3	N
Carya laciniosa	Big Shellbark Hickory	G5			S3	N
Cirsium discolor	Field Thistle	G5			S3	N
Coreopsis tripteris	Tall Coreopsis	G5			S2	N
Desmodium canadense	Showy Tick-trefoil	G5			S2	N
Echinochloa walteri	Walter's Barnyard Grass	G5			S3	N
Euonymus atropurpurea var. atropurpurea	Burning Bush	G5			S3	N
Eupatorium altissimum	Tall Boneset	G5			S1	N
Euthamia gymnospermoides	Flat-topped Goldenrod	G5			S1	N
Fraxinus profunda	Pumpkin Ash	G4			S2?	N
Gaura biennis	Biennial Gaura	G5			S3	N
Gleditsia triacanthos	Honey Locust	G5			S2	N
Gymnocladus dioicus	Kentucky Coffee-tree	G5	THR	THR	S2	N
Heuchera americana var. americana	Rock-geranium	G5			S2	N
Hibiscus moscheutos ssp. moscheutos	Swamp Rosemallow	G5	SC	SC	S3	N
Hydrastis canadensis	Golden Seal	G4	THR	THR	S2	N
Lactuca floridana var. floridana	Woodland Lettuce	G5			S2	N
Leucospora multifida	Conobea	G5			S2	N
Ludwigia polycarpa	Many-fruit False-loosestrife	G4			S2S3	N
Lycopus rubellus	Taperleaf Bugleweed	G5			S3	N
Lycopus virginicus	Virginia Bugleweed	G5			S3	N
Lythrum alatum	Winged Loosestrife	G5			S3	N
Morus rubra	Red Mulberry	G5	END	END	S2	N
Nelumbo lutea	American Lotus	G4			S2	N
Nuphar advena	Yellow Pond-lily	G5			S3	N
Phyla lanceolata	Fog Fruit	G5			S2	N
Ptelea trifoliata	Hop Tree	G5	THR	THR	S3	N
Quercus shumardii	Shumard's Oak	G5	SC	SC	S3	N
Ranunculus hispidus var. hispidus	Bristly Buttercup	G5T5			S3	N
Ratibida pinnata	Gray-headed Coneflower	G5			S3	N
Rosa setigera	Climbing Prairie Rose	G5	SC	SC	S3	N

Scientific Name	Common Name	GRank	COSEWIC	MNR	SRank	NatStatus
Silphium terebinthinaceum var. terebinthinaceum	Prairie Dock	G4G5T4T5			S1	N
Sisyrinchium albidum	White Blue-eyed Grass	G5?			S1	N
Smilax ecirrhata	Upright Greenbrier	G5?			S3?	N
Smilax illinoensis	Illinois Greenbrier	G4?			S2?	N
Solidago riddellii	Riddell's Goldenrod	G5	SC	SC	S3	N
Solidago rigida ssp. rigida	Stiff Goldenrod	G5T5			S3	N
Spiranthes magnicamporum	Great Plains Ladies'-tresses	G4			S3?	N
Thaspium trifoliatum var. aureum	Purple Meadow-parsnip	G5T5			S2	N
Triosteum perfoliatum	Perfoliate Horse Gentian	G5			S1	N
Verbesina alternifolia	Wingstem	G5			S3	N
Vernonia gigantea ssp. gigantea	Giant Ironweed	G5			S1?	N
Vernonica missurica	Ironweed	G4G5			S3?	N
Veronicastrum virginicum	Culver's-root	G4			S2	N
Zizania aquatica	Southern Wild Rice	G5			S3	N

Significant Habitat of Endangered/Threatened Species

A total of five (5) floral Species at Risk where documented in the Big Creek watershed during the 2009 field surveys.

Six (6) specimens which closely resemble Red Mulberry (*Morus rubra*), an Endangered species, were documented. Red Mulberry and White Mulberry (*M. alba*) hybridize and White Mulberry trees were noted growing throughout the watershed. The specimens which are reported as Red Mulberry are worthy of genetic analysis to ascertain purity, due to the physical characteristics noted at the time in the field. The vegetation communities associated with the sightings of Red Mulberry are listed in the following chart. Half of all of the sightings occurred in Deciduous Forest communities, while the other half of the sightings occurred equally in Woodland, Plantation and on the edge of Shallow Marsh communities.

Ecoelement (Vegetation Type) Name	ELC Code (2008)	Occurrence in Vegetation Type
Fresh - Moist Oak Carolinian Deciduous Forest	FODM10-2	16.67%
Naturalized Deciduous Plantation	FODM12	16.67%
Fresh - Moist Shagbark Hickory Deciduous Forest	FODM9-4	16.67%
Fresh - Moist Deciduous Woodland	WODM5	16.67%
Managed White Pine Coniferous Plantation	CUT_1-2	16.67%
Reed Canary Grass Mineral Shallow Marsh	MASM1-14	16.67%

One (1) population of Willow Aster (*Aster praealtus* var. *praealtus*), a Threatened species, was documented growing in a Gray Dogwood Deciduous Thicket (THDM5-1) vegetation community.

One (1) large, mature and several small, young specimens of Kentucky Coffee-tree (*Gymnocladus dioicus*), a Threatened species, were documented in one location. The vegetation communities associated with this population include Black Walnut dominated Fresh - Moist Deciduous Woodland (WODM5) and Gray Dogwood Deciduous Thicket (THDM5-1).

Fourteen (14) sightings of Hop Tree (*Ptelea trifoliata*), a Threatened species, were documented growing along the shoreline of Lake Erie. The vegetation communities associated with the sightings of Hop Tree are listed in the following chart.

Ecoelement (Vegetation Type) Name	ELC Code (2008)	Count	Occurrence in Vegetation Type
Mineral Treed Shoreline	SHTM1	6	42.86%
Cottonwood Mineral Treed Shoreline	SHTM1-1	5	35.71%
Mineral Open Shoreline	SHOM1	3	21.43%

Seven (7) populations of Golden Seal (*Hydrastis canadensis*), a Threatened species, were documented growing in mature forest. The vegetation communities associated with the sightings of Golden Seal are listed in the following chart.

Ecoelement (Vegetation Type) Name	ELC Code (2008)	Count	Occurrence in Vegetation Type
Dry - Fresh Oak - Hickory Deciduous Forest	FODM2-2	6	85.71%
Fresh - Moist Shagbark Hickory Deciduous Forest	FODM9-4	1	14.29%

Wildlife

Faunal Inventory

A total of 259 animal species were identified from 2562 observations recorded during the faunal inventory for the watershed.

Birds

A total of 159 species of birds were documented within the Big Creek watershed during the 2009 faunal surveys.

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
American Black Duck	G5	S4			Rare Local	10%		
American Coot	G5	S4B	NAR	NAR	Rare Local	10%		Area Sensitive
American Crow	G5	S5B			Common Widespread	78%		
American Goldfinch	G5	S5B			Common Widespread	86%		
American Kestrel	G5	S4			Uncommon Widespread	70%	Regional Concern	
American Redstart	G5	S5B			Uncommon Widespread	29%		Area Sensitive
American Robin	G5	S5B			Common Widespread	89%		
American White Pelican	G4	S2B	NAR	THR	Not a breeder			
American Wigeon	G5	S4			Very Rare Local	5%		
American Woodcock	G5	S4B			Uncommon Widespread			
Bald Eagle	G5	S2N,S4B	NAR	SC	Uncommon Widespread	37%		Area Sensitive
Baltimore Oriole	G5	S4B			Common Widespread	94%	Regional Concern, Regional Stewardship	
Bank Swallow	G5	S4B			Uncommon Widespread	54%	Regional Stewardship	

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
Barn Swallow	G5	S4B			Common Widespread	89%		
Bay-breasted Warbler	G5	S5B			Not a breeder			
Belted Kingfisher	G5	S4B			Uncommon Widespread	75%	Regional Concern	
Black Tern	G4	S3B	NAR	SC	Rare Local	10%		Area Sensitive
Black-and-white Warbler	G5	S5B			Not a breeder			Area Sensitive
Black-billed Cuckoo	G5	S5B			Uncommon Widespread	54%	Regional Concern, Regional Stewardship	
Blackburnian Warbler	G5	S5B			Not a breeder			Area Sensitive
Black-capped Chickadee	G5	S5			Common Widespread	67%		
Black-crowned Night-Heron	G5	S3B,S3N			Uncommon Local	21%		
Blackpoll Warbler	G5	S4B			Not a breeder			
Black-throated Blue Warbler	G5	S5B			Not a breeder			
Black-throated Green Warbler	G5	S5B			Not a breeder			
Blue Jay	G5	S5			Common Widespread	83%		
Blue-gray Gnatcatcher	G5	S4B			Uncommon Widespread	45%		Area Sensitive
Blue-headed Vireo	G5	S5B			Not a breeder			
Blue-winged Teal	G5	S4			Uncommon Local	35%		
Blue-winged Warbler	G5	S4B			Rare Local	10%	Continental Concern	
Bobolink	G5	S4B			Common Widespread	64%	Regional Concern, Regional Stewardship	
Brown Thrasher	G5	S4B			Uncommon Widespread	64%	Regional Concern	
Brown-headed Cowbird	G5	S4B			Common Widespread	83%		
Canada Goose	G5	S5			Common Widespread	83%		
Canada Warbler	G5	S4B	THR	SC	Not a breeder			
Canvasback	G5	S1B,S4N			Not a breeder			
Carolina Wren	G5	S4			Common Widespread	86%		
Caspian Tern	G5	S3B	NAR	NAR	Very Rare Local	5%		
Cedar Waxwing	G5	S5B			Common Widespread	89%		

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
Chestnut-sided Warbler	G5	S5B			Rare Local	10%		
Chimney Swift	G5	S4B,S4N	THR	THR	Common Local	75%	Management interest	
Chipping Sparrow	G5	S5B			Common Widespread	78%		
Common Grackle	G5	S5B			Abundant Widespread	94%		
Common Merganser	G5	S5B,S5N			Not a breeder			
Common Moorhen	G5	S4B			Rare Local	18%		
Common Tern	G5	S4B	NAR	NAR	Rare Local	10%		
Common Yellowthroat	G5	S5B			Common Widespread	75%		
Cooper's Hawk	G5	S4	NAR	NAR	Common Widespread	78%		Area Sensitive
Double-crested Cormorant	G5	S5B	NAR	NAR	Common Local	32%		
Downy Woodpecker	G5	S5			Common Widespread	89%		
Eastern Bluebird	G5	S5B	NAR	NAR	Uncommon Widespread	54%		
Eastern Kingbird	G5	S4B			Common Widespread	91%	Regional Concern	
Eastern Phoebe	G5	S5B			Uncommon Widespread	48%		
Eastern Screech-Owl	G5	S4	NAR	NAR	Common Widespread	78%		
Eastern Wood-Pewee	G5	S4B			Common Widespread	81%	Regional Concern	
European Starling	G5	SNA			Abundant Widespread	94%		
Field Sparrow	G5	S4B			Uncommon Widespread	59%	Regional Concern	
Forster's Tern	G5	S2B	DD	DD	Rare Local	13%		Area Sensitive
Gadwall	G5	S4			Rare Local	8%		
Gray Catbird	G5	S4B			Common Widespread	81%		
Gray-cheeked Thrush	G5	S2S4B			Not a breeder			
Great Blue Heron	G5	S4			Uncommon Widespread	35%		
Great Crested Flycatcher	G5	S4B			Common Widespread	64%		
Great Egret	G5	S2B			Rare Local	13%		
Great Horned Owl	G5	S4			Uncommon Widespread	67%		
Greater Yellowlegs	G5	S4B,S4N			Not a breeder			
Green Heron	G5	S4B			Uncommon Widespread	67%		
Green-winged Teal	G5	S4			Very Rare Local	8%		

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
Hairy Woodpecker	G5	S5			Uncommon Widespread	45%		Area Sensitive
Herring Gull	G5	S5B,S5N			Uncommon Local	32%		
Hooded Merganser	G5	S5B,S5N			Very Rare Local	5%		
Hooded Warbler	G5	S3B	THR	SC	Very Rare Local	8%	THR	
Horned Lark	G5	S5B			Common Widespread	75%		
House Finch	G5	SNA			Common Widespread	83%		
House Sparrow	G5	SNA			Common Widespread			
House Wren	G5	S5B			Common Widespread	86%		
Indigo Bunting	G5	S4B			Common Widespread	78%		
Killdeer	G5	S5B,S5N			Common Widespread	88%		
King Rail	G4	S2B	END	END	Very Rare Local	5%		Area Sensitive
Least Bittern	G5	S4B	THR	THR	Rare Local	13%		Area Sensitive
Least Flycatcher	G5	S4B			Rare Local	13%		Area Sensitive
Least Sandpiper	G5	S4B,S5N			Not a breeder			
Lesser Scaup	G5	S4			Very rare Local			
Lesser Yellowlegs	G5	S4B,S4N			Not a breeder			
Lincoln's Sparrow	G5	S5B			Not a breeder			
Louisiana Waterthrush	G5	S3B	SC	SC	Not a breeder		SC	
Magnolia Warbler	G5	S5B			Not a breeder			
Mallard	G5	S5			Common Widespread	91%		
Marsh Wren	G5	S4B			Uncommon Local	35%		
Merlin	G5	S5B	NAR	NAR	Not a breeder			
Mourning Dove	G5	S5			Common Widespread	86%		
Mourning Warbler	G5	S4B			Not a breeder			
Mute Swan	G5	SNA			Common Local	27%		
Nashville Warbler	G5	S5B			Not a breeder			
Northern Cardinal	G5	S5			Common Widespread	94%		
Northern Flicker	G5	S4B			Common Widespread	89%	Regional Concern	

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
Northern Harrier	G5	S4B	NAR	NAR	Uncommon Widespread	43%	Regional Concern	Area Sensitive
Northern Parula	G5	S4B			Not a breeder			Area Sensitive
Northern Pintail	G5	S5			Very Rare Local	5%		
Northern Rough-winged Swallow	G5	S4B			Common Widespread	78%		
Northern Shoveler	G5	S4			Rare Local	10%		
Northern Waterthrush	G5	S5B			Not a breeder			
Orchard Oriole	G5	S4B			Common Widespread	72%		
Osprey	G5	S5B			Very rare Local	2%		
Ovenbird	G5	S4B			Rare Local	16%		
Palm Warbler					Not a breeder			
Peregrine Falcon	G4	S3B	SC	THR	Very rare Local	5%		
Philadelphia Vireo	G5	S5B			Not a breeder			
Pied-billed Grebe	G5	S4B,S4N			Uncommon Local	21%		
Prothonotary Warbler	G5	S1B	END	END	Very Rare Local	8%	END	Area Sensitive
Purple Martin	G5	S4B			Common Widespread	78%		
Red-bellied Woodpecker	G5	S4			Common Widespread	67%		
Red-eyed Vireo	G5	S5B			Common Widespread	86%		
Redhead	G5	S2B,S4N			Rare Local	10%		Area Sensitive
Red-headed Woodpecker	G5	S4B	THR	SC	Uncommon Widespread	40%	THR	Rapidly declining
Red-tailed Hawk	G5	S5	NAR	NAR	Common Widespread	75%		
Red-winged Blackbird	G5	S4			Abundant Widespread	94%		
Ring-billed Gull	G5	S5B,S4N			Common Local	13%		
Ring-necked Duck	G5	S5			Not a breeder			
Rock Pigeon	G5	SNA			Common Widespread	75%		
Rose-breasted Grosbeak	G5	S4B			Uncommon Widespread	51%	Regional Stewardship	
Ruby-crowned Kinglet	G5	S4B			Not a breeder			
Ruby-throated Hummingbird	G5	S5B			Common Widespread	67%		
Ruddy Duck	G5	S4B,S4N			Uncommon Local	24%		

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
Sandhill Crane	G5	S5B			Rare Local	10%		Area Sensitive
Savannah Sparrow	G5	S4B			Common Widespread	72%	Regional Concern	Area Sensitive
Scarlet Tanager	G5	S4B			Uncommon Widespread	37%		Area Sensitive
Sedge Wren	G5	S4B	NAR	NAR	Rare Local	13%		
Semi-palmated Plover	G5	S4B,S4N			Not a breeder			
Semipalmated Sandpiper	G5	S3B,S4N			Not a breeder			
Snowy Egret	G5	SNA			Not a breeder			Very rare visitor
Solitary Sandpiper	G5	S4B			Not a breeder			
Song Sparrow	G5	S5B			Common Widespread	83%		
Sora	G5	S4B			Uncommon Widespread	40%		
Spotted Sandpiper	G5	S5			Common Widespread	83%		
Summer Tanager	G5	SNA			Not a breeder			Rare spring migrant
Swainson's Thrush	G5	S4B			Not a breeder			
Swamp Sparrow	G5	S5B			Uncommon Widespread	48%		
Tennessee Warbler	G5	S5B			Not a breeder			
Tree Swallow	G5	S4B			Common Widespread	94%		
Tufted Titmouse	G5	S4			Locally Common	29%		Area Sensitive
Turkey Vulture	G5	S5B			Common Widespread	75%		
Veery	G5	S4B			Rare Local	10%		
Virginia Rail	G5	S5B			Rare Local	13%		
Warbling Vireo	G5	S5B			Common Widespread	81%		
Whip-poor-will	G5	S4B	THR	THR	Very Rare Local	2%		
White-breasted Nuthatch	G5	S5			Uncommon Widespread	45%		Area Sensitive
White-crowned Sparrow	G5	S4B			Not a breeder			
White-eyed Vireo	G5	S2B			Very rare Local	5%		
White-throated Sparrow	G5	S5B			Very rare	2%		
Wild Turkey	G5	S5			Uncommon Widespread	59%		
Willow Flycatcher	G5	S5B			Uncommon Widespread	67%	Continental Concern	
Wilson's Snipe	G5	S5B			Not a breeder			

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	% Squares	Partners in Flight Level of Concern	Other Significance
Wilson's Warbler	G5	S4B			Not a breeder			
Wood Duck	G5	S5			Common Widespread	70%		
Wood Thrush	G5	S4B			Uncommon Widespread	67%	Continental Concern, Regional Concern	
Yellow Warbler	G5	S5B			Common Widespread	86%		
Yellow-billed Cuckoo	G5	S4B			Uncommon Widespread	70%		
Yellow-rumped Warbler	G5	S5B			Not a breeder			

Mammals

A total of 16 species of mammals were documented within the Big Creek watershed during the 2009 faunal surveys.

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
Beaver	G5	S5			Rare Local	
Coyote	G5	S5			Common Widespread	
Eastern Cottontail	G5	S5			Common Widespread	
Eastern Gray Squirrel	G5	S5			Common Widespread	
Little Brown Bat	G5	S5			Common Widespread	
Long-tailed Weasel	G5	S4			Common Widespread	
Meadow Vole	G5	S5			Common Widespread	
Muskrat	G5	S5			Common Widespread	
Northern Raccoon	G5	S5			Common Widespread	
Northern Short-tailed Shrew	G5	S5			Common Widespread	
Peromyscus mouse species [Deer or White-footed]					Common Widespread	
Red Fox	G5	S5			Common Widespread	
Striped Skunk	G5	S5			Common Widespread	
Virginia Opossum	G5	S4			Common Widespread	
White-tailed Deer	G5	S5			Common Widespread	
Woodchuck	G5	S5			Uncommon Local	

Reptiles

A total of 10 species of reptiles were documented within the Big Creek watershed during the 2009 faunal surveys.

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
Blanding's Turtle	G4	S3	THR	THR	Uncommon Local	Restricted to marshes
Butler's Gartersnake	G4	S2	THR	THR	Locally common Restricted range	
Common Watersnake	G5T5	S5	NAR	NAR	Uncommon Restricted Range	Known only from Pelee, Hillman, Canard River, Big Creek, Ojibway, Bob-lo
Dekay's Brownsnake	G5	S5	NAR	NAR	Locally common Widespread	
Eastern Foxsnake	GNR	S2	END	END	Locally common Widespread	Essex County has the bulk of the world population of this snake
Eastern Gartersnake	G5T5	S5			Common Widespread	
Midland Painted Turtle	G5T5	S5			Common Widespread	
Northern Map Turtle	G5	S3	SC	SC	Common Local	Area Sensitive
Snapping Turtle	G5	S3	SC	SC	Common Widespread	
Stinkpot			THR	THR	Rare Local	

Amphibians

A total of 6 species of amphibians were documented within the Big Creek watershed during the 2009 faunal surveys.

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
"Blue-spotted" Salamander	G5	S4			Very rare Local	
American Bullfrog	G5	S4			Common Widespread	Area Sensitive
American Toad	G5	S5			Common Widespread	
Green Frog	G5	S5			Common Widespread	
Northern Leopard Frog	G5	S5	NAR	NAR	Common Widespread	
Western Chorus Frog	G5TNR	S4	NAR	NAR	Common Widespread	

Butterflies

A total of 38 species of butterflies were documented within the Big Creek watershed during the 2009 faunal surveys.

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
American Lady					Common Widespread	
Black Swallowtail					Common Widespread	
Broad-winged Skipper					Increasingly common	
Bronze Copper					Common Widespread	
Cabbage White					Common Widespread	
Clouded Sulphur					Common Widespread	
Common Buckeye					Rare and erratic immigrant	
Common Sootywing	G5	S3			Uncommon Local	
Common Wood-Nymph					Common Widespread	
Crescent species					Common Widespread	

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
Dun Skipper					Common Widespread	
Eastern Comma					Uncommon Widespread	
Eastern Tailed Blue					Common Widespread	
Eastern Tiger Swallowtail					Common Widespread	
European Skipper					Common Widespread	
Eyed Brown					Locally common	
Giant Swallowtail	G5	S3			Common Widespread	Common in Essex, rare in Ontario
Gray Hairstreak					Rare Local	
Great Spangled Fritillary					Common Widespread	
Hackberry Emperor	G5	S2			Uncommon Local	
Juvenal's Duskywing					Uncommon Widespread	
Least Skipper					Common Widespread	
Little Wood-Satyr					Common Widespread	
Monarch	G5	S2N,S4B	SC	SC	Common Widespread	
Mourning Cloak					Common Widespread	
Northern Broken Dash					Common Widespread	
Orange Sulphur					Common Widespread	
Painted Lady					Erratic immigrant	
Peck's Skipper					Common Widespread	
Question Mark					Common Widespread	
Red Admiral					Common Widespread	
Red-spotted Purple					Common Widespread	
Silver-spotted Skipper					Common Widespread	
Spicebush Swallowtail					Common Widespread	
Spring Azure					Common Widespread	
Summer Azure					Common Widespread	
Tawny Emperor	G5	S2S3			Uncommon Local	
Viceroy					Common Widespread	

Odonata

A total of 30 species of Odonata (dragonflies and damselflies) were documented within the Big Creek watershed during the 2009 faunal surveys.

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
Black Saddlebags					Common	
Blue Dasher					Common	
Bluet species						
Citrine Forktail	G5	S2			Rare	
Common Baskettail					Common	
Common Green Darner					Common	
Common Whitetail					Common	
Dot-tailed Whiteface					Common	
Eastern Amberwing					Common	
Eastern Forktail					Common	
Eastern Pondhawk					Common	
Emerald Spreadwing					Common	
Fragile Forktail					Common	
Halloween Pennant					Uncommon	
Lance-tipped Darner					Common	

Common Name	GRank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Other Significance
Meadowhawk species						
Orange Bluet					Common	
Red Saddlebags					Rare	
Ruby Meadowhawk					Common	
Slender Spreadwing					Common	
Spot-winged Glider					Common	
Spreadwing species						
Swamp Darner	G5	S2S3			Uncommon	
Tule Bluet					Common	
Twelve-spotted Skimmer					Common	
Vesper Bluet					Rare	
Wandering Glider					Uncommon	
White-faced Meadowhawk					Uncommon	
Widow Skimmer					Common	
Yellow-legged Meadowhawk					Common	

Fishes

Fish sampling was not completed as part of the Big Creek watershed study. A total of 47 species have been identified and reported from fish sampling activities since 1979. Sources include sampling efforts of the Department of Fisheries and Oceans, Essex Region Conservation Authority, Ministry of Natural Resources, and the Royal Ontario Museum.

Common Name	GRank	SRank	COSEWIC	MNR	Collection Year	
					1979-1999	2000-2013
Alewife	G5			SE	X	X
Ameiurus sp.						X
Banded Killifish	G5	S5	NAR	NAR		X
Bigmouth Buffalo	G5	SU	NAR	NAR	X	X
Black Bullhead	G5	S4			X	X
Black Crappie	G5	S4			X	X
Bluegill	G5	S5			X	X
Bluntnose Minnow	G5	S5	NAR	NAR	X	X
Bowfin	G5	S4				X
Brook Silverside	G5	S4	NAR	NAR	X	X
Brown Bullhead	G5	S5			X	X
Carassius auratus x Cyprinus carpio						X
Central Mudminnow	G5	S5			X	
Channel Catfish	G5	S4				X
Common Carp	G5	SNA		SE	X	X
Common Shiner	G5	S5			X	
Creek Chub	G5	S5				X
Emerald Shiner	G5	S5			X	X
Fathead Minnow	G5	S5			X	X
Freshwater Drum	G5	S5				X
Gizzard Shad	G5	S4			X	X
Golden Redhorse	G5	S4	NAR	NAR		X
Goldfish	G5	SNA		SE	X	X
Green Sunfish	G5	S4	NAR	NAR	X	X
Ictiobus sp.						X
Largemouth Bass	G5	S5			X	X
Lepomis sp.						X
Logperch	G5	S5			X	X
Longnose Gar	G5	S4			X	X
Mimic Shiner	G5	S5			X	X
Northern Hog Sucker	G5	S4			X	

Common Name	GRank	SRank	COSEWIC	MNR	Collection Year	
					1979-1999	2000-2013
Northern Pike	G5	S5			X	
Pumpkinseed	G5	S5			X	X
Quillback	G5	S4			X	X
Rainbow Smelt	G5	S5			X	
Rock Bass	G5	S5			X	X
Round Goby	G5	SNA				X
Smallmouth Bass	G5	S5				X
Spotfin Shiner	G5	S4			X	X
Spottail Shiner	G5	S5				X
Striped Shiner	G5	S4	NAR	NAR		X
Trout-perch	G5	S5			X	
Tubenose Goby	GR	SNA				X
White Bass	G5	S4			X	X
White Perch	G5	SNA		SE	X	X
White Sucker	G5	S5			X	X
Yellow Perch	G5	S5			X	X

Significant Fauna

The following 66 significant faunal species were documented in the Big Creek Watershed:

Taxonomic Group	Common Name	GRrank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Partners in Flight Level of Concern	Other Significance
Amphibians	American Bullfrog	G5	S4			Common Widespread		Area Sensitive
Birds	American Coot	G5	S4B	NAR	NAR	Rare Local		Area Sensitive
	American Kestrel	G5	S4			Uncommon Widespread	Regional Concern	
	American Redstart	G5	S5B			Uncommon Widespread		Area Sensitive
	American White Pelican	G4	S2B	NAR	THR	Not a breeder		
	Bald Eagle	G5	S2N,S4B	NAR	SC	Uncommon Widespread		Area Sensitive
	Baltimore Oriole	G5	S4B			Common Widespread	Regional Concern, Regional Stewardship	
	Belted Kingfisher	G5	S4B			Uncommon Widespread	Regional Concern	
	Black Tern	G4	S3B	NAR	SC	Rare Local		Area Sensitive
	Black-and-white Warbler	G5	S5B			Not a breeder		Area Sensitive
	Black-billed Cuckoo	G5	S5B			Uncommon Widespread	Regional Concern, Regional Stewardship	
	Blackburnian Warbler	G5	S5B			Not a breeder		Area Sensitive
	Black-crowned Night-Heron	G5	S3B,S3N			Uncommon Local		
	Blue-gray Gnatcatcher	G5	S4B			Uncommon Widespread		Area Sensitive

Taxonomic Group	Common Name	GRrank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Partners in Flight Level of Concern	Other Significance
	Blue-winged Warbler	G5	S4B			Rare Local	Continental Concern	
	Bobolink	G5	S4B			Common Widespread	Regional Concern, Regional Stewardship	
	Brown Thrasher	G5	S4B			Uncommon Widespread	Regional Concern	
	Canada Warbler	G5	S4B	THR	SC	Not a breeder		
	Canvasback	G5	S1B,S4N			Not a breeder		
	Caspian Tern	G5	S3B	NAR	NAR	Very Rare Local		
	Chimney Swift	G5	S4B,S4N	THR	THR	Common Local	Management interest	
	Cooper's Hawk	G5	S4	NAR	NAR	Common Widespread		Area Sensitive
	Eastern Kingbird	G5	S4B			Common Widespread	Regional Concern	
	Eastern Wood-Pewee	G5	S4B			Common Widespread	Regional Concern	
	Field Sparrow	G5	S4B			Uncommon Widespread	Regional Concern	
	Forster's Tern	G5	S2B	DD	DD	Rare Local		Area Sensitive
	Gray-cheeked Thrush	G5	S2S4B			Not a breeder		
	Great Egret	G5	S2B			Rare Local		
	Hairy Woodpecker	G5	S5			Uncommon Widespread		Area Sensitive
	Hooded Warbler	G5	S3B	THR	SC	Very Rare Local	THR	
	King Rail	G4	S2B	END	END	Very Rare Local		Area Sensitive
	Least Bittern	G5	S4B	THR	THR	Rare Local		Area Sensitive
	Least Flycatcher	G5	S4B			Rare Local		Area Sensitive
	Louisiana Waterthrush	G5	S3B	SC	SC	Not a breeder	SC	
	Northern Flicker	G5	S4B			Common Widespread	Regional Concern	
	Northern Harrier	G5	S4B	NAR	NAR	Uncommon Widespread	Regional Concern	Area Sensitive
	Northern Parula	G5	S4B			Not a breeder		Area Sensitive
	Peregrine Falcon	G4	S3B	SC	THR	Very rare Local		
	Prothonotary Warbler	G5	S1B	END	END	Very Rare Local	END	Area Sensitive
	Redhead	G5	S2B,S4N			Rare Local		Area Sensitive
	Red-headed Woodpecker	G5	S4B	THR	SC	Uncommon Widespread	THR	Rapidly declining
	Sandhill Crane	G5	S5B			Rare Local		Area Sensitive
	Savannah Sparrow	G5	S4B			Common Widespread	Regional Concern	Area Sensitive

Taxonomic Group	Common Name	GRrank	SRank	COSEWIC	MNR	Essex (Breeding) Status	Partners in Flight Level of Concern	Other Significance
	Scarlet Tanager	G5	S4B			Uncommon Widespread		Area Sensitive
	Semipalmated Sandpiper	G5	S3B,S4N			Not a breeder		
	Snowy Egret	G5	SNA			Not a breeder		Very rare visitor
	Summer Tanager	G5	SNA			Not a breeder		Rare spring migrant
	Tufted Titmouse	G5	S4			Locally Common		Area Sensitive
	Whip-poor-will	G5	S4B	THR	THR	Very Rare Local		
	White-breasted Nuthatch	G5	S5			Uncommon Widespread		Area Sensitive
	White-eyed Vireo	G5	S2B			Very rare Local		
	Willow Flycatcher	G5	S5B			Uncommon Widespread	Continental Concern	
	Wood Thrush	G5	S4B			Uncommon Widespread	Continental Concern, Regional Concern	
Butterflies	Common Sootywing	G5	S3			Uncommon Local		
	Giant Swallowtail	G5	S3			Common Widespread		Common in Essex, rare in Ontario
	Hackberry Emperor	G5	S2			Uncommon Local		
	Monarch	G5	S2N,S4B	SC	SC	Common Widespread		
	Tawny Emperor	G5	S2S3			Uncommon Local		
Odonata	Citrine Forktail	G5	S2			Rare		
	Swamp Darner	G5	S2S3			Uncommon		
Reptiles	Blanding's Turtle	G4	S3	THR	THR	Uncommon Local		Restricted to marshes
	Butler's Gartersnake	G4	S2	THR	THR	Locally common Restricted range		
	Eastern Foxsnake	GNR	S2	END	END	Locally common Widespread		Essex County has the bulk of the world population of this snake
	Northern Map Turtle	G5	S3	SC	SC	Common Local		Area Sensitive
	Snapping Turtle	G5	S3	SC	SC	Common Widespread		
	Stinkpot			THR	THR	Rare Local		

Significant Habitat of Endangered/Threatened Species

One (1) sighting of a King Rail (*Rallus elegans*), an Endangered species, was documented and associated with the following vegetation communities:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Mixed Shallow Aquatic	Pondweed Mixed Shallow Aquatic Type	SAM_1-4
	Duckweed Mixed Shallow Aquatic Type	SAM_1-2
Deciduous Forest	Fresh - Moist Cottonwood Deciduous Forest	FODM8-3

Six (6) sightings (totaling 7 individuals) of Prothonotary Warbler (*Protonotaria citrea*), an Endangered species, were documented with the habitat generally described as “swamp forest”, “flooded swamp” or “flooded woodlot”. Vegetation communities associated with these sightings, in order of prevalence, include:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Mixed Shallow Aquatic	Pondweed Mixed Shallow Aquatic	SAM_1-4
	Duckweed Mixed Shallow Aquatic	SAM_1-2
Deciduous Forest	Fresh - Moist Cottonwood Deciduous Forest	FODM8-3
Meadow Marsh	Reed-canary Grass Graminoid Mineral Meadow Marsh	MAMM1-3
Thicket Swamp	Buttonbush Mineral Deciduous Thicket Swamp	SWTM5-1
Treed Shoreline	Cottonwood Mineral Treed Shoreline Type	SHTM1-1

Eighteen (18) sightings of the Eastern Foxsnake (*Pantherophis gloydi*), an Endangered species, were documented with the habitat generally described as “grassland”, “marsh/marsh edge”, “field/field edge”, “woodland edge”, “side of road”, or “yard”. Vegetation communities associated with these sightings, in order of prevalence, include:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Deciduous Thicket	Hawthorn Deciduous Shrub Thicket	THDM2-11
	Gray Dogwood Deciduous Thicket	THDM5-1
	Gray Dogwood Deciduous Shrub Thicket	THDM2-4
Meadow Marsh	Common Reed Graminoid Mineral Meadow Marsh	MAMM1-12
Deciduous Swamp	Swamp Maple Mineral Deciduous Swamp	SWDM3-3
Deciduous Forest	Fresh - Moist Oak Carolinian Deciduous Forest	FODM10-2
	Fresh - Moist Manitoba Maple Lowland Deciduous Forest	FODM7-7
Shallow Marsh	Forb Mineral Shallow Marsh	MASM2-1
Shrub Shoreline	Mineral Shrub Shoreline	SHSM1
Mixed Meadow	Dry - Fresh Mixed Meadow	MEMM3

Eighteen (18) sightings (totaling 15 individuals and 4 nests) of Least Bittern (*Ixobrychus exilis*), a Threatened species, were documented with the habitat generally described as “Cattail Marsh”. Vegetation communities associated with these sightings, in order of prevalence, include:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Shallow Marsh	Cattail Mineral Shallow Marsh	MASM1-1
	Common Reed Mineral Shallow Marsh	MASM1-12
Floating-leaved Shallow Aquatic	American Lotus Floating-leaved Shallow Aquatic	SAF_1-2
	Duckweed Floating-leaved Shallow Aquatic	SAF_1-3
Mixed Shallow Aquatic	Duckweed Mixed Shallow Aquatic	SAM_1-2

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Meadow Marsh	Common Reed Graminoid Mineral Meadow Marsh	MAMM1-12
Deciduous Forest	Naturalized Deciduous Plantation	FODM12
	Fresh - Moist Oak Carolinian Deciduous Forest	FODM10-2

Nineteen sightings (totaling 41 individuals) of Blanding's Turtle (*Emydoidea blandingii*), a Threatened species, were documented with the habitat generally described as "marsh". Vegetation communities associated with these sightings, in order of prevalence, include:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Shallow Marsh	Cattail Mineral Shallow Marsh	MASM1-1
	Forb Mineral Shallow Marsh	MASM2-1
	Common Reed Mineral Shallow Marsh	MASM1-12
Floating-leaved Shallow Aquatic	Duckweed Floating-leaved Shallow Aquatic	SAF_1-3
Mixed Shallow Aquatic	Duckweed Mixed Shallow Aquatic	SAM_1-2
	Pondweed Mixed Shallow Aquatic	SAM_1-4
Meadow Marsh	Reed-canary Grass Graminoid Mineral Meadow Marsh	MAMM1-3
Deciduous Swamp	Silver Maple Mineral Deciduous Swamp	SWDM3-2
	Willow Mineral Deciduous Swamp	SWDM4-1
Deciduous Thicket	Gray Dogwood Deciduous Thicket	THDM5-1
Deciduous Forest	Fresh - Moist Cottonwood Deciduous Forest	FODM8-3

In addition, 3 sightings (totaling 4 individuals) of Butler's Gartersnake (*Thamnophis butleri*), a Threatened species, were also documented, with the habitat generally described as "in long grass". Vegetation communities associated with these sightings include:

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)
Deciduous Thicket	Gray Dogwood Deciduous Thicket	THDM5-1
	Native Deciduous Regeneration Thicket	THDM4-1
	Gray Dogwood Deciduous Shrub Thicket	THDM2-4
Forb Meadow	Goldenrod Forb Meadow Type	MEFM1-1

One (1) sighting of a visitor Peregrine Falcon (*Falco peregrinus*), a Threatened species, was documented with the activity generally described as "hunting over marsh". The vegetation community most closely associated with this sighting includes the American Lotus Floating-leaved Shallow Aquatic Type (SAF_1-2).

Four (4) sightings (totaling 6 individuals) of Chimney Swift (*Chaetura pelagica*), a Threatened species, was documented with the activity generally described as "foraging overhead". The vegetation communities most closely associated with these sightings include Dry - Fresh Hickory Deciduous Forest (FODM2-3), Dry - Fresh Hackberry Deciduous Forest (FODM4-3) and Gray Dogwood Deciduous Shrub Thicket (THDM2-4).

In addition, one (1) sighting of a Stinkpot or Eastern Musk Turtle (*Sternotherus odoratus*), a Threatened species, was documented with the habitat generally being described as "on land near marsh". The vegetation community most closely associated with this sighting includes the Hawthorn Deciduous Shrub Thicket (THDM2-11).

Significant Wildlife Habitat

The Big Creek watershed contains colonial bird nesting sites of Least Bittern, Forster's Tern, Black Tern, Marsh wren, Red-winged Blackbird and Common Grackle. The open water wetlands are significant as a waterfowl stopover and staging area, while the diverse upland areas within the watershed provide landbird migratory stopover areas as well as stopover habitat for the Monarch butterfly. Some areas within the watershed provide Turkey Vulture summer roosting areas as well as suitable areas of reptile hibernacula for the following species: Eastern Foxsnake, Butler's Gartersnake, Northern Watersnake, DeKay's Brownsnake, Snapping Turtle, Midland Painted Turtle, Blanding's Turtle, Common Map Turtle, and the Common Musk Turtle. The wetland is of sufficient quality to support a population of Bullfrogs.

Ten (10) different provincially rare (S1 to S3) vegetation communities were also identified within the watershed (see the section on Significant Communities for further information). The faunal inventory recorded the presence of area-sensitive bird species. Some areas of forest are extensive enough to provide interior forest habitat. In addition, the forested areas within the watershed contain numerous amphibian woodland breeding ponds. The beach shoreline provides significant opportunities for turtle nesting, and many areas within the watershed provide habitats for species of conservation concern (see section on Significant Species for further information). Many areas within the watershed are located on sections of Big Creek and/or its tributaries which function as animal movement corridors.

Environmental Impacts, Opportunities & Conclusions

Ownership

It is important to note that the very extensive and diverse Big Creek Marsh wetland is extremely productive with respect to wildlife breeding, especially marsh birds. The conditions which lend themselves to this area being such an extremely productive wetland are largely due to the fact that most of the wetland area is privately owned and managed. This wetland would not be as productive biologically if this area was intensively used by the public, especially during the breeding season. The current owners and managers are to be commended for their outstanding stewardship and management of their properties.

Hunting/Trapping

Extensive hunting occurs throughout the watershed (especially in the lower reaches) and includes hunting of waterfowl, white-tailed deer and possibly wild turkey.

Critical Issues

Exotic and/or Invasive Species

Plants

The rapid spread of invasive plants has become a major concern among ecologists, naturalists, biologists and land managers worldwide. From an ecological perspective, the concern centres on the displacement of diverse native species, the impacts on interrelated species (those that rely on native plants for food or other values), and reduced genetic diversity (Havinga, 2000).

The following exotic invasive plant species were documented as occurring in the Big Creek watershed:

Exotic Invasive Flora		
Scientific Name	**Common Name**	**Type**
Acer negundo	Manitoba Maple	Tree
Alliaria petiolata	Garlic Mustard	Forb
Alnus glutinosa	European Black Alder	Shrub
Butomus umbellatus	Flowering-rush	Forb
Cirsium arvense	Crepping Thistle	Forb
Coronilla varia	Crown-vetch	Forb
Elaeagnus umbellata	Autumn Olive	Shrub
Hesperis matronalis	Dame's Rocket	Forb
Lonicera japonica	Japanese Honeysuckle	Woody Vine
Lonicera maackii	Amur Honeysuckle	Shrub
Lonicera tatarica	Tartarian Honeysuckle	Shrub
Lythrum salicaria	Slender-spike Loosestrife	Forb
Morus alba	White Mulberry	Tree
Phragmites australis	Common Reed	Grass
Potamogeton crispus	Curly Pondweed	Forb
Rhamnus cathartica	Buckthorn	Shrub
Rhamnus frangula	Glossy Buckthorn	Shrub
Rosa multiflora	Rambler Rose	Shrub

ELC vegetation community mapping included the delineation of polygons where either Common Reed (*Phragmites australis*) or Purple Loosestrife (*Lythrum salicaria*) were the dominant species. The following table and accompanying map summarize the extent of these two highly problematic species for the areas surveyed during the 2009 field inventories.

Community Series	Ecoelement (Vegetation Type) Name	ELC Code (2008)	Ac	Ha
Meadow Marsh	Common Reed Graminoid Mineral Meadow Marsh	MAMM1-12	37.26	15.08
Shallow Marsh	Common Reed Mineral Shallow Marsh	MASM1-12	266.47	107.84
	Purple Loosestrife Mineral Shallow Marsh	MASM2-4	6.40	2.59

Wildlife

Raccoons, while native to our region, may pose a significant threat to certain populations of wildlife, if their populations become high. Raccoons. are omnivorous. Animal foods include crayfish, clams, fish, frogs, snails, insects, turtles and their eggs, mice, rabbits, muskrats, and the eggs and young of ground-nesting birds and waterfowl (Boggess, 1994). The population of raccoons within the lower portions of Big Creek is extremely high due to the significant signs of turtle nest predation in the area, especially along the beach. This intensive predation by raccoons may be impacting the sustainability of Threatened populations of Blanding's Turtles and Eastern Musk Turtles.

The House Wren is the most serious (and damaging) competitor for nest sites of the Endangered Prothonotary Warbler; predation of nests by raccoons also figures prominently (OMNR, 2011a).

In addition, feral cats feed extensively on songbirds, game birds, rodents, and other wildlife and pose a serious threat to native wildlife, particularly birds (Fitzwater, 1994; University of Nebraska, 2011).

Hydrology/Wetland Management

At the mouth of Big Creek, the managers of the existing private dam structure at the outlet influence the water level regime within the main marsh basin as well as further upstream. As part of the Ministry of the Environment Permit to Take Water, an Operational Plan has been written recommending a concept water level management regime for managing the marsh vegetation successional cycle.

In addition, Site #23 (Mans Marsh) consists of a series of dyked wetland impoundments, which are currently falling into a state of disrepair. Water enters this site from the two feeding tributaries in the north, and leaves the site through a pumphouse located at the end of Erie Avenue.

Adjacent Land Use Issues

Agriculture is by far the predominant land use adjacent to the remaining natural features within the Big Creek watershed. Land conversion to agricultural row crops and associated drainage works has been identified as the single greatest cause of wetland loss and degradation in Ontario. Habitat loss, fragmentation and water quality degradation due to sedimentation and contaminated runoff are the key problems facing all of our remaining natural features within the Essex region, due to our highly settled landscape.

Literature Cited

Boggess, E.K. 1994. Racoons. Pages C101-C108. In S.E. Hygnstrom, R.. M. Timm, and G.E. Larson (eds) Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension Service, Lincoln, Nebraska, United States. *http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1038 &context=icwdmhandbook*.

Essex Region Conservation Authority (ERCA). 2002. Essex Region Biodiveristy Conservation Strategy – Habitat Restoration and Enhancement Guidelines. Dan Lebedyk, Project Co-ordinator. Essex, Ontario. 181 pp.

Essex Region Conservation Authority. 2013. Essex Region Natural Heritage System Strategy - (An Update to the Essex Region Biodiversity Conservation Strategy). Essex, Ontario. 319 pages.

Fitzwater, W.D. 1994. House cats (Feral). Pages C45-C49. In S.E. Hygnstrom, R.. M. Timm, and G.E. Larson (eds) Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension Service, Lincoln, Nebraska, United States. *http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1031 &context=icwdmhandbook*.

Havinga, D., 2000. Sustaining Biodiversity: A Strategic Plan for Managing Invasive Plants in Southern Ontario. City of Toronto Parks & Rec. Toronto, ON

Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig and S. McMurray. 1998. Ecological Land Classification for Southern Ontario: First Approximation and its Application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02. 225 pp.

Lee, H.T. 2011 (in development). Ecosystems of Ontario – Provincial Ecological land Classification Program, Southern Ontario's Integrated Sampling Protocols (ISP): Field Application Manual (Prototype SELC Product). Ontario Ministry of Natural Resources, Southern Region Information Management and Spatial Analysis Unit.

Ontario Ministry of Natural Resources (OMNR). 2011a. DRAFT Recovery Strategy for the Prothonotary Warbler (Protonotaria citrea) in Ontario. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario. i + 3 pp. + Appendix vi + 26 pp. Adoption of the Recovery Strategy for the Prothonotary Warbler (*Protonotaria citrea*) in Canada (Environment Canada, 2011).

University of Nebraska – Lincoln Extension. 2010. Feral Cats and Their Management. Publication number EC1781. Institute of Agriculture and Natural Resources, University of Nebraska – Lincoln. Lincoln, Nebraska, United States. *http://www.ianrpubs.unl.edu/sendIt/ec1781.pdf*.

Revised Big Creek Marsh Water Level Operational Plan

Dan Lebedyk, *Conservation Biologist*

The following provides the rationale and technical details for recommended adjustments to the original Big Creek Water Level Operational Plan, as proposed by Ducks Unlimited Canada in 2007 (see Appendix). These revisions to the water level management regime are recommended in order to better facilitate the growth of rich hemi-marsh within the lower Big Creek Marsh basin.

While the original Operational Plan (Appendix) is acceptable insofar as recommended relative levels overtime, the management of the marsh could benefit from an extended period of shallow water immediately following a dewatering of the marsh. This dewatering could be as a result of natural deficits in water availability or deliberate pumping out of the basin in order to initiate re-vegetation (i.e. a drawdown). If the water levels were managed in the first year following a dewatering to achieve a maximum average depth of 10 cm (4 in), in the second year a depth of 10-20 cm (4-8 in), and in the third year depths averaging 20-30 cm (8-12 in), then the resulting diversity of the marsh would be greater than at present. This diversity would include a higher component of shallow water marsh communities, such as Bulrush Mineral Shallow Marsh Type (MASM1-2) and Arrowhead Mineral Shallow Marsh Type (MASM2-3) which was noticeably scarce within this site, considering the last dewatering occurred only 4 years prior, in 2005. Most of the aerial extent of wetland was composed of the deeper water American Lotus Floating-leaved Shallow Aquatic Type (SAF_1-2) Community, which while valuable as a provincially rare community type, is indicative of a much later stage (i.e., deeper water stage) in a marsh's successional cycle.

In addition, if future dewatering events are planned for the main Big Creek marsh, it is recommended that those events occur as quickly as possible to trigger mass germination of the marsh seedbank in the resulting mudflats. Once vegetation is well established, water should be added to encourage dense vegetation growth. This will assist in preventing the spread of Common Reed (Phragmites australis) which would most likely spread aggressively and extensively during slow removal and drying of the marsh.

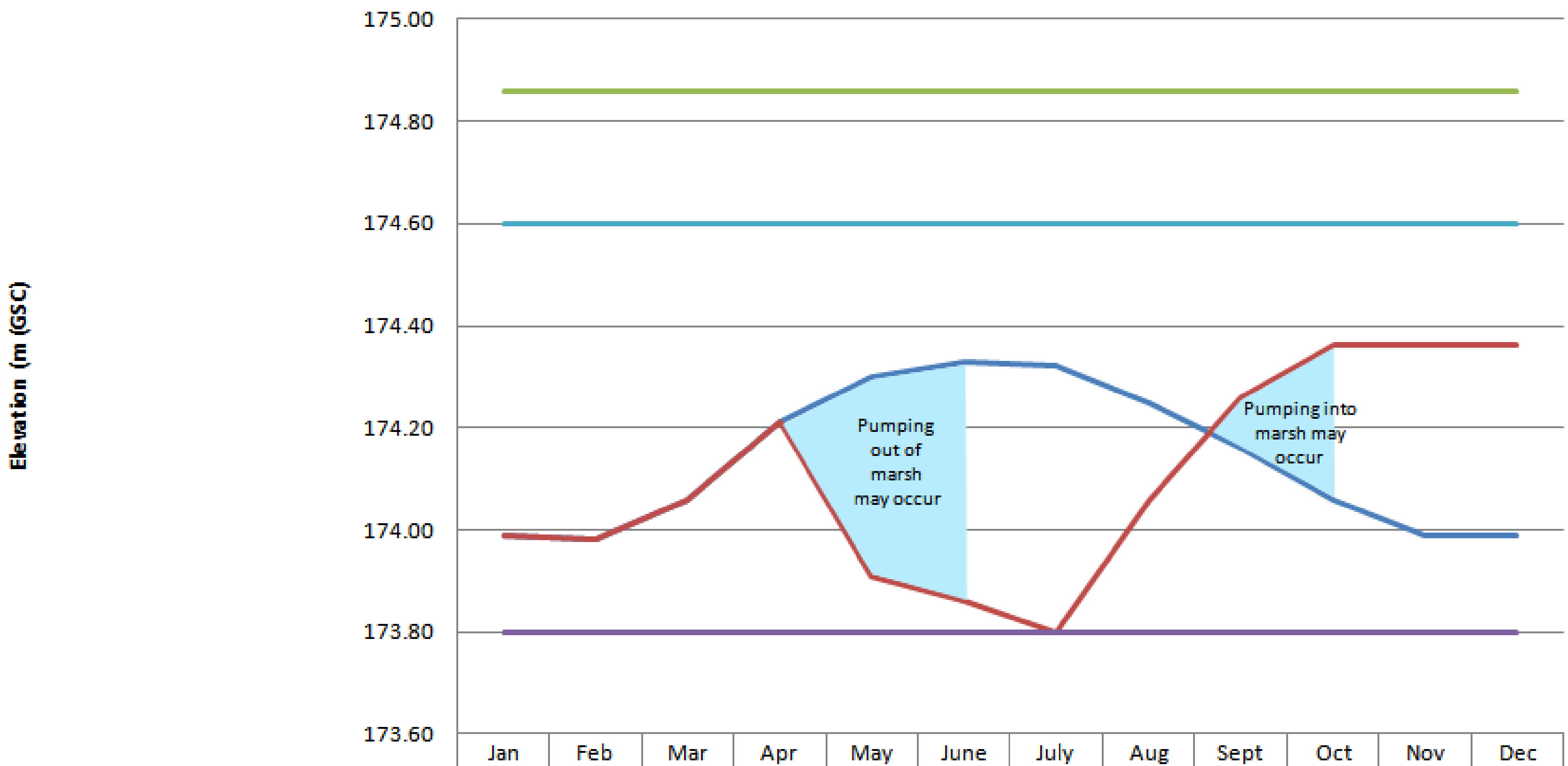
The following charts and diagrams illustrate the proposed adjustments and the desired results. These charts and figures attempt to depict a comparison between the effects of the original DUC Operational Plan and the ERCA recommended adjusted plan. In general, the adjustments recommend maintaining a shallower water level regime in the first two years of growth following a dewatering event, allowing for the establishment of emergent marsh vegetation. Excessive depths of water within these first two growing seasons of a revegetating marsh will result in the loss of newly established emergents due to flooding.

DU Proposed pumping schedule during the open water marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	173.99	173.98	174.06	174.21	173.91	173.86	173.80	174.06	174.26	174.36	174.36	174.36
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.19	0.18	0.26	0.41	0.11	0.06	0.00	0.26	0.46	0.56	0.56	0.56
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	7.48	7.09	10.24	16.14	4.33	2.36	0.00	10.24	18.11	22.05	22.05	22.05
Depth (in) @ 174.07 m GSC (50% area of basin)	-3.15	-3.54	-0.39	5.51	-6.30	-8.27	-10.63	-0.39	7.48	11.42	11.42	11.42
Depth (in) @ 174.55 m GSC (75% area of basin)	-22.05	-22.44	-19.29	-13.39	-25.20	-27.17	-29.53	-19.29	-11.42	-7.48	-7.48	-7.48
Expected Water Taking by Pumping	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No
Direction of Pumping	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	-	-	Into Marsh	Into Marsh	-	-
Contingency Water Taking by Pumping	-	-	-	-	-	>173.91	>173.85	>174.16	>174.36	>174.46	-	-
Direction of Pumping	-	-	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-

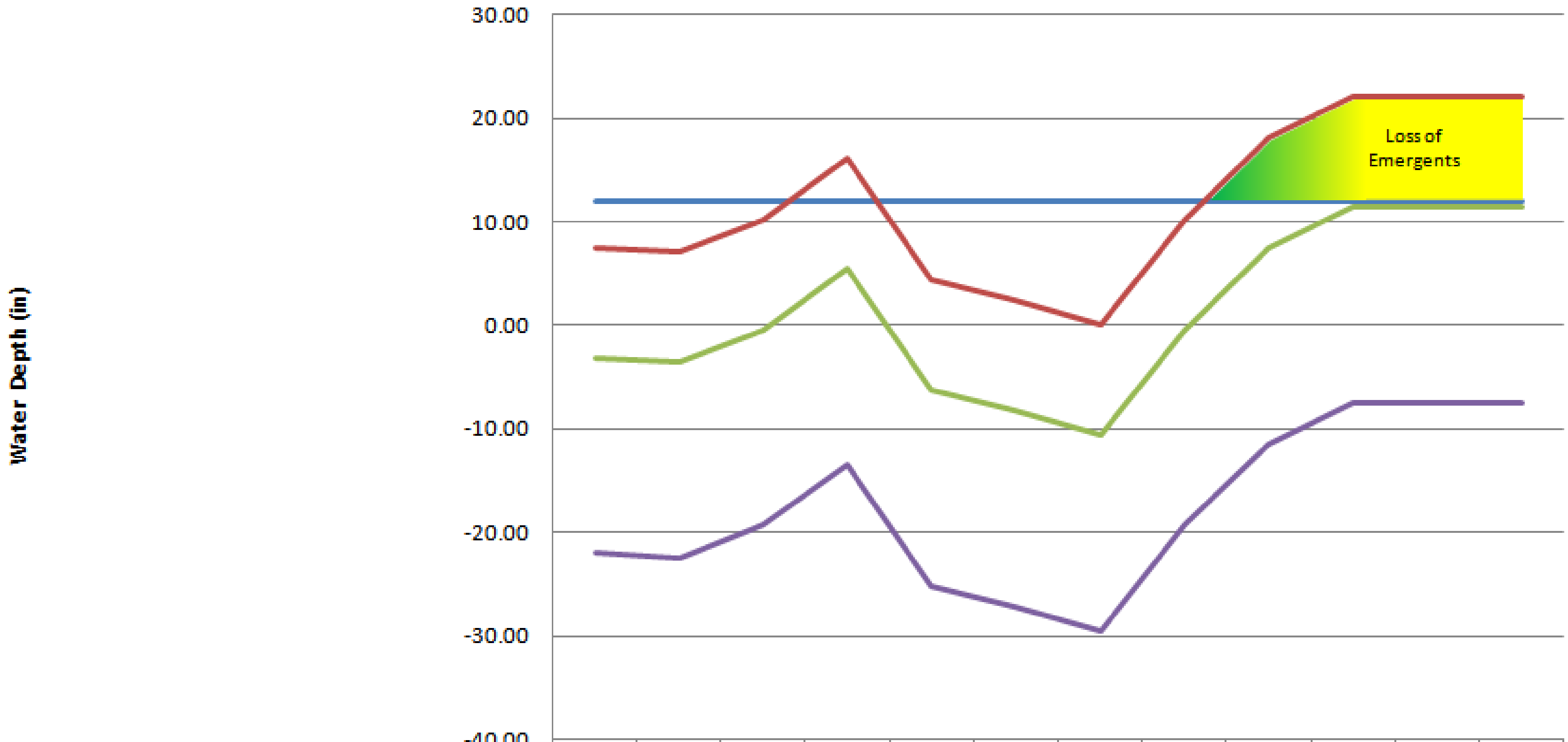
Essex Region Conservation Authority

DU Proposed W/L Mgmt. - Open Water Marsh Phase



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	173.99	173.98	174.06	174.21	173.91	173.86	173.80	174.06	174.26	174.36	174.36	174.36
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60

DU Proposed Water Depths - Open Water Marsh Phase



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	7.48	7.09	10.24	16.14	4.33	2.36	0.00	10.24	18.11	22.05	22.05	22.05
Depth (in) @ 174.07 m GSC (50% area of basin)	-3.15	-3.54	-0.39	5.51	-6.30	-8.27	-10.63	-0.39	7.48	11.42	11.42	11.42
Depth (in) @ 174.55 m GSC (75% area of basin)	-22.05	-22.44	-19.29	-13.39	-25.20	-27.17	-29.53	-19.29	-11.42	-7.48	-7.48	-7.48

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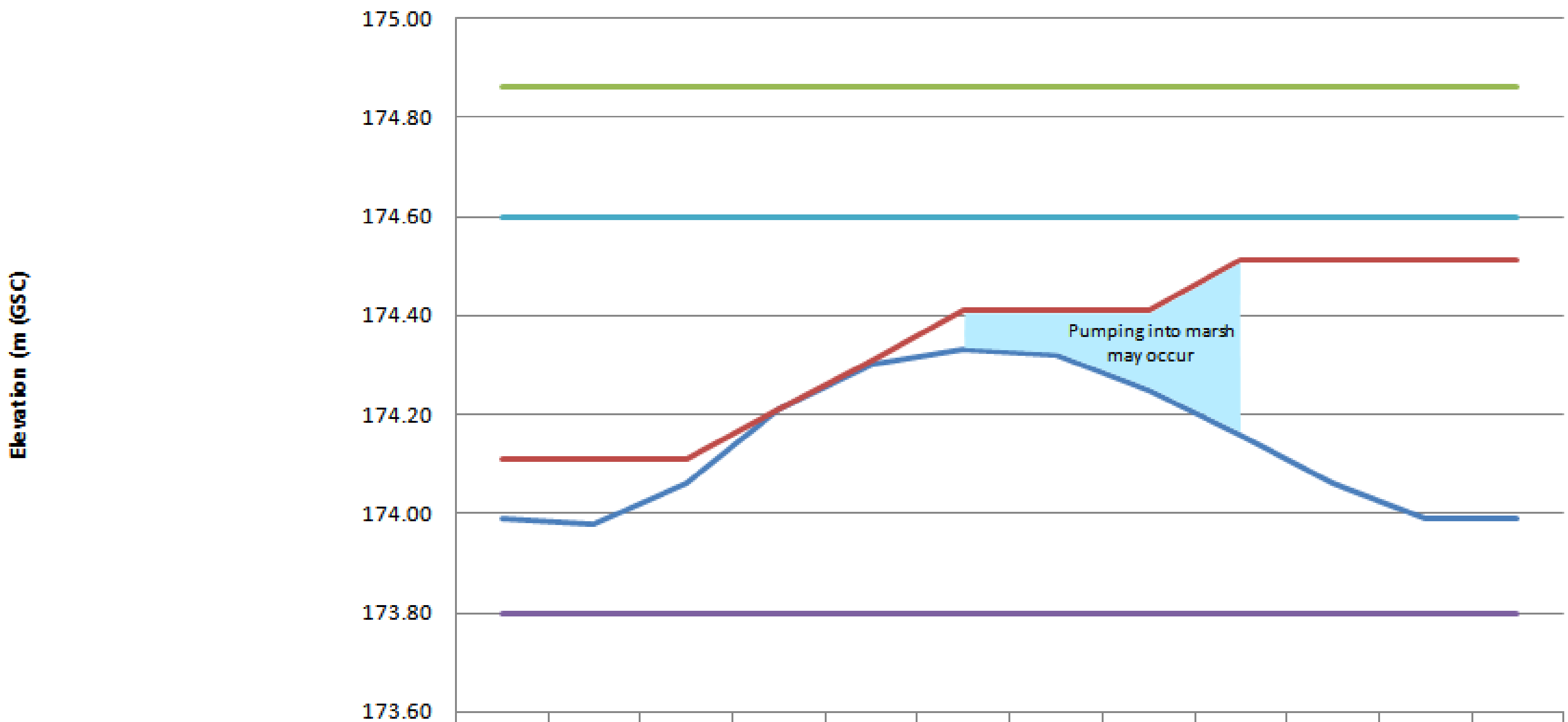
DU Proposed pumping schedule during the hemi-marsh phase.

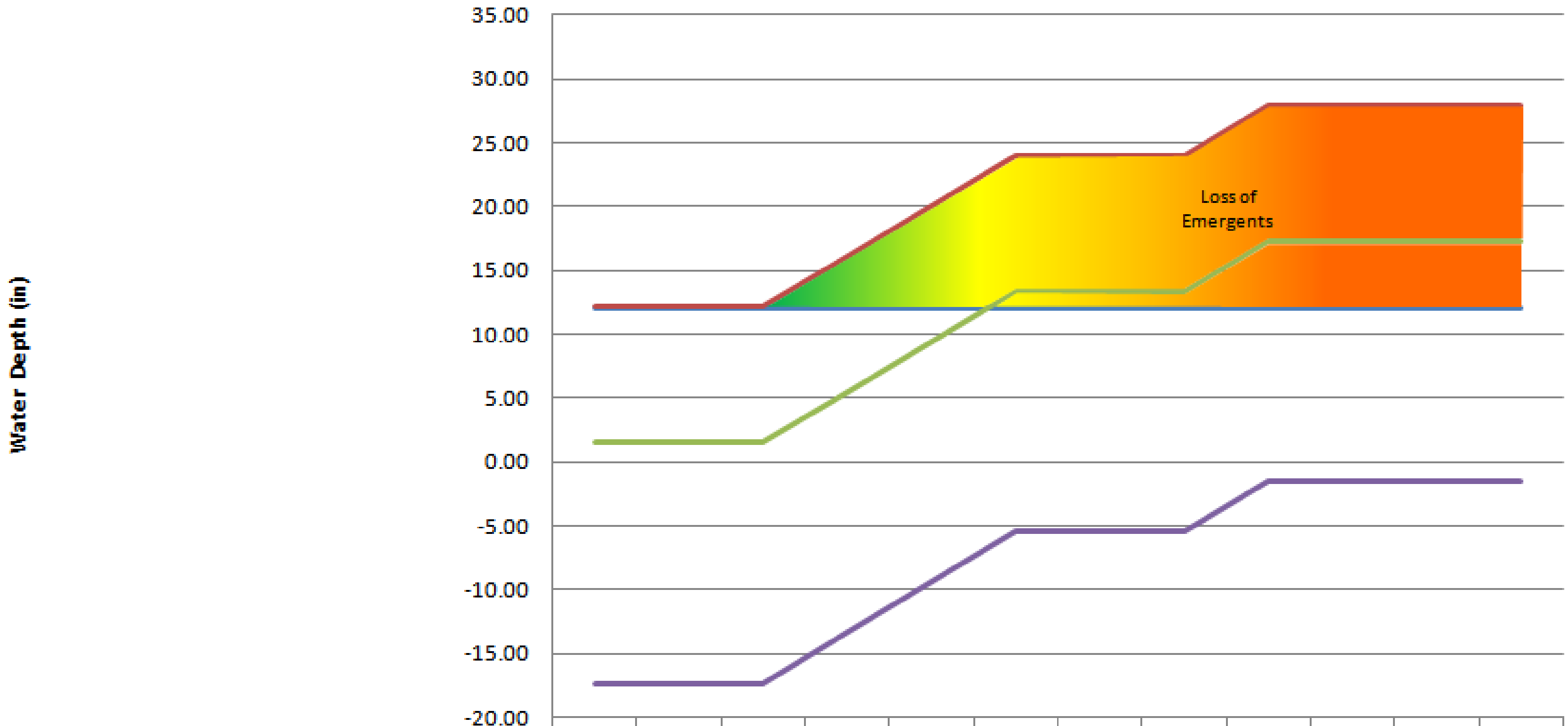
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.11	174.11	174.11	174.21	174.31	174.41	174.41	174.41	174.51	174.51	174.51	174.51
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.31	0.31	0.31	0.41	0.51	0.61	0.61	0.61	0.71	0.71	0.71	0.71
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	12.20	12.20	12.20	16.14	20.08	24.02	24.02	24.02	27.95	27.95	27.95	27.95
Depth (in) @ 174.07 m GSC (50% area of basin)	1.57	1.57	1.57	5.51	9.45	13.39	13.39	13.39	17.32	17.32	17.32	17.32
Depth (in) @ 174.55 m GSC (75% area of basin)	-17.32	-17.32	-17.32	-13.39	-9.45	-5.51	-5.51	-5.51	-1.57	-1.57	-1.57	-1.57
Expected Water Taking by Pumping	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No
Direction of Pumping	-	-	-	-	-	Into Marsh	Into Marsh	Into Marsh	Into Marsh	-	-	-
Contingency Water Taking by Pumping	-	-	-	-	>174.51	>174.51	>174.51	-	-	-	-	-
Direction of Pumping	-	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	-	-	-	-	-

DU Proposed W/L Mgmt. - Hemi-marsh Phase



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.11	174.11	174.11	174.21	174.31	174.41	174.41	174.41	174.51	174.51	174.51	174.51
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60

DU Proposed Water Depths - Hemi-marsh Phase



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	12.20	12.20	12.20	16.14	20.08	24.02	24.02	24.02	27.95	27.95	27.95	27.95
Depth (in) @ 174.07 m GSC (50% area of basin)	1.57	1.57	1.57	5.51	9.45	13.39	13.39	13.39	17.32	17.32	17.32	17.32
Depth (in) @ 174.55 m GSC (75% area of basin)	-17.32	-17.32	-17.32	-13.39	-9.45	-5.51	-5.51	-5.51	-1.57	-1.57	-1.57	-1.57

DU Proposed pumping schedule during the overgrown marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.31	174.31	174.31	174.41	174.51	174.60	174.60	174.60	174.51	174.51	174.51	174.51
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.51	0.51	0.51	0.61	0.71	0.80	0.80	0.80	0.71	0.71	0.71	0.71
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	20.08	20.08	20.08	24.02	27.95	31.50	31.50	31.50	27.95	27.95	27.95	27.95
Depth (in) @ 174.07 m GSC (50% area of basin)	9.45	9.45	9.45	13.39	17.32	20.87	20.87	20.87	17.32	17.32	17.32	17.32
Depth (in) @ 174.55 m GSC (75% area of basin)	-9.45	-9.45	-9.45	-5.51	-1.57	1.97	1.97	1.97	-1.57	-1.57	-1.57	-1.57
Expected Water Taking by Pumping	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Direction of Pumping	-	-	-	-	Into Marsh	Into Marsh	Into Marsh	Into Marsh	-	-	-	-
Contingency Water Taking by Pumping	-	-	-	≥174.60	≥174.60	≥174.60	≥174.60	≥174.60	≥174.60	≥174.60	-	-
Direction of Pumping	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-

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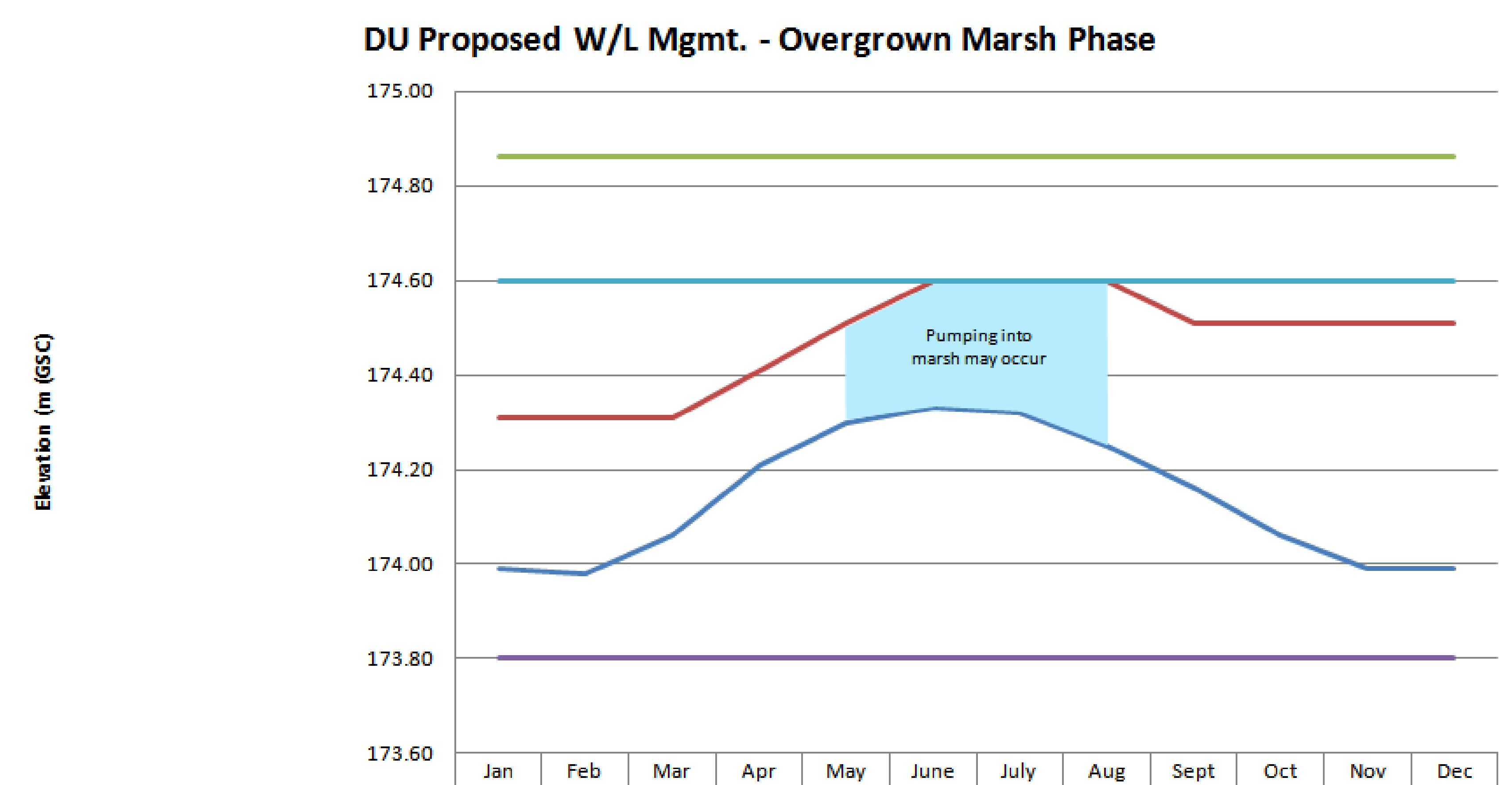
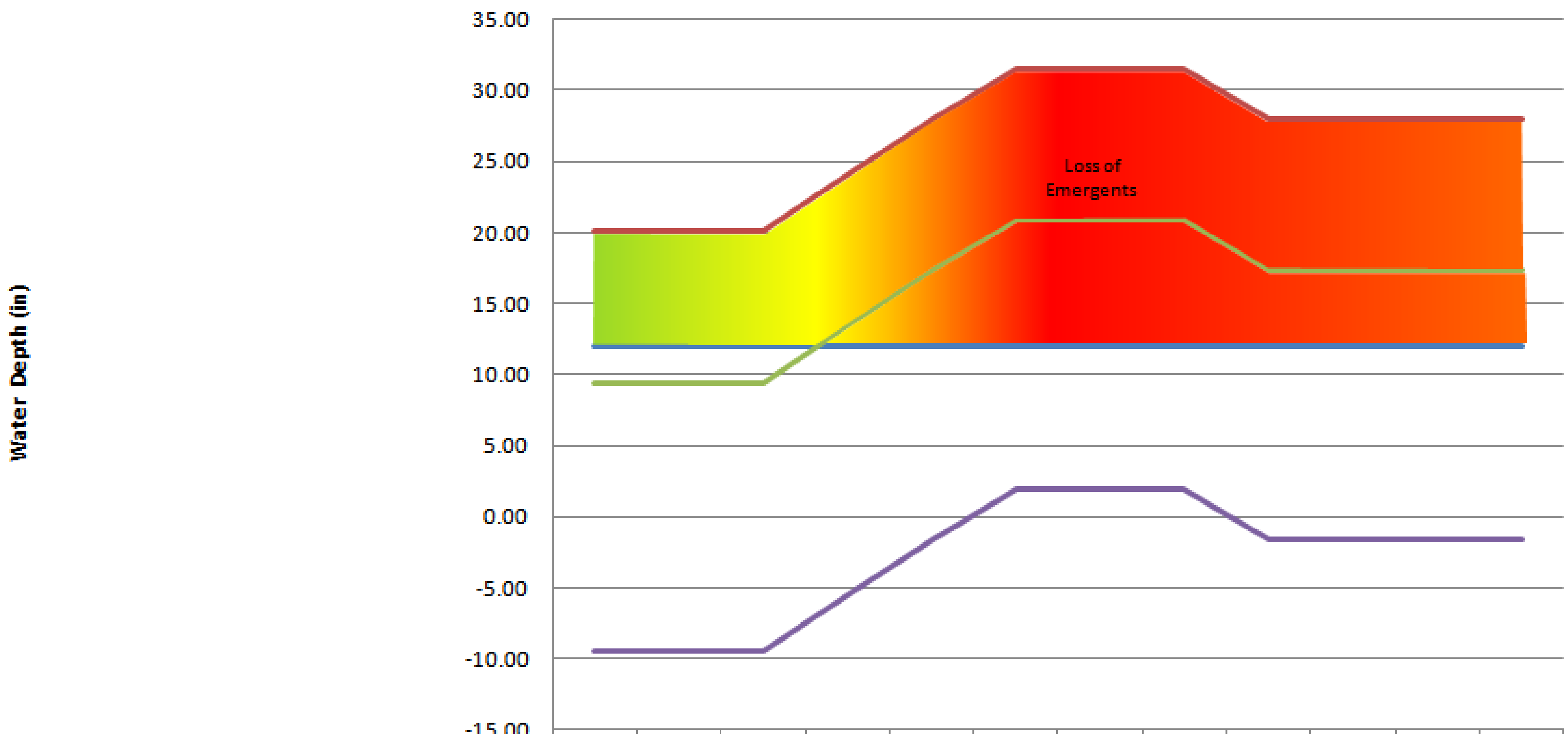


	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.31	174.31	174.31	174.41	174.51	174.60	174.60	174.60	174.51	174.51	174.51	174.51
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60

DU Proposed Water Depths - Overgrown Marsh Phase

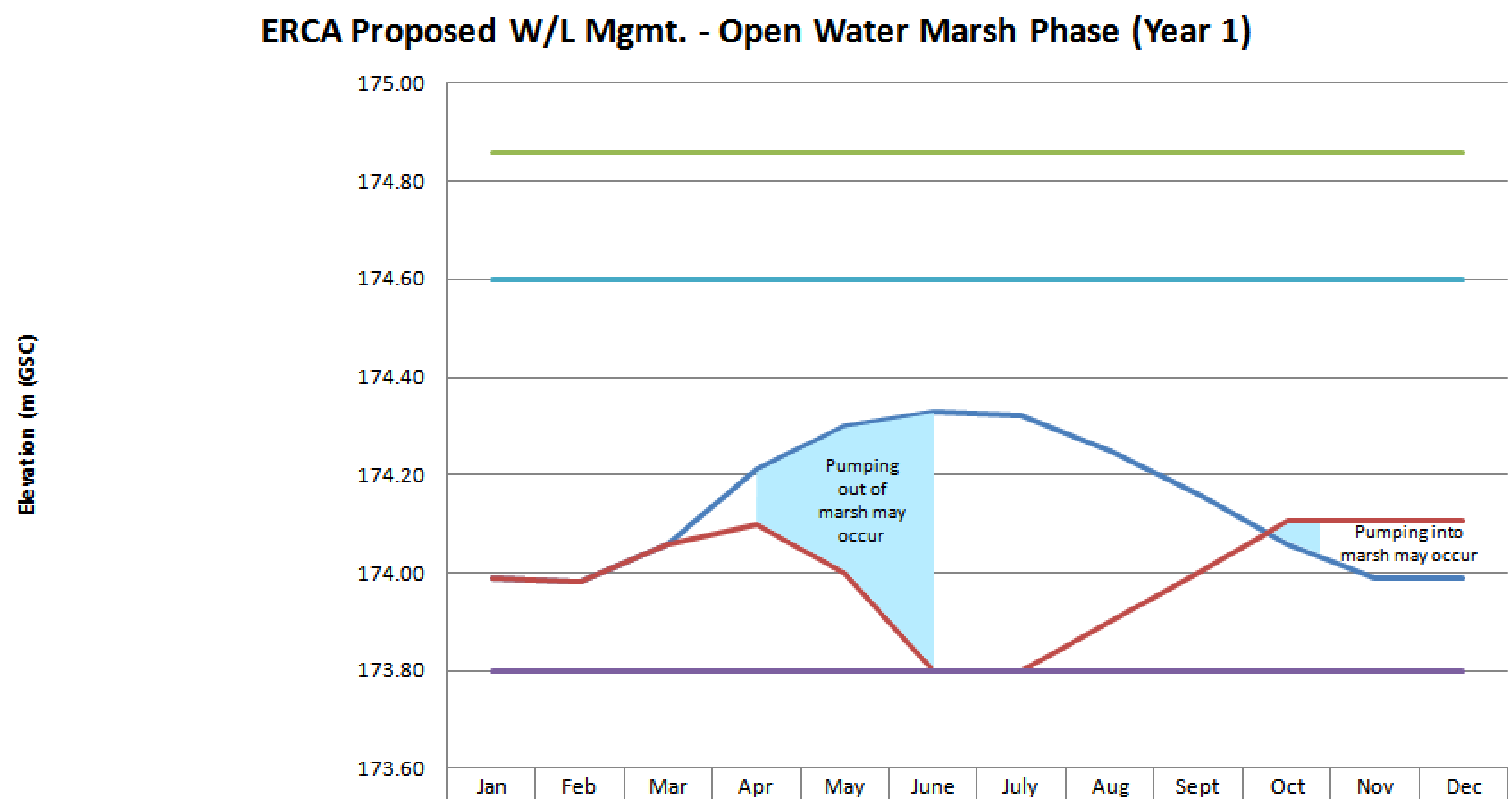


	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	20.08	20.08	20.08	24.02	27.95	31.50	31.50	31.50	27.95	27.95	27.95	27.95
Depth (in) @ 174.07 m GSC (50% area of basin)	9.45	9.45	9.45	13.39	17.32	20.87	20.87	20.87	17.32	17.32	17.32	17.32
Depth (in) @ 174.55 m GSC (75% area of basin)	-9.45	-9.45	-9.45	-5.51	-1.57	1.97	1.97	1.97	-1.57	-1.57	-1.57	-1.57

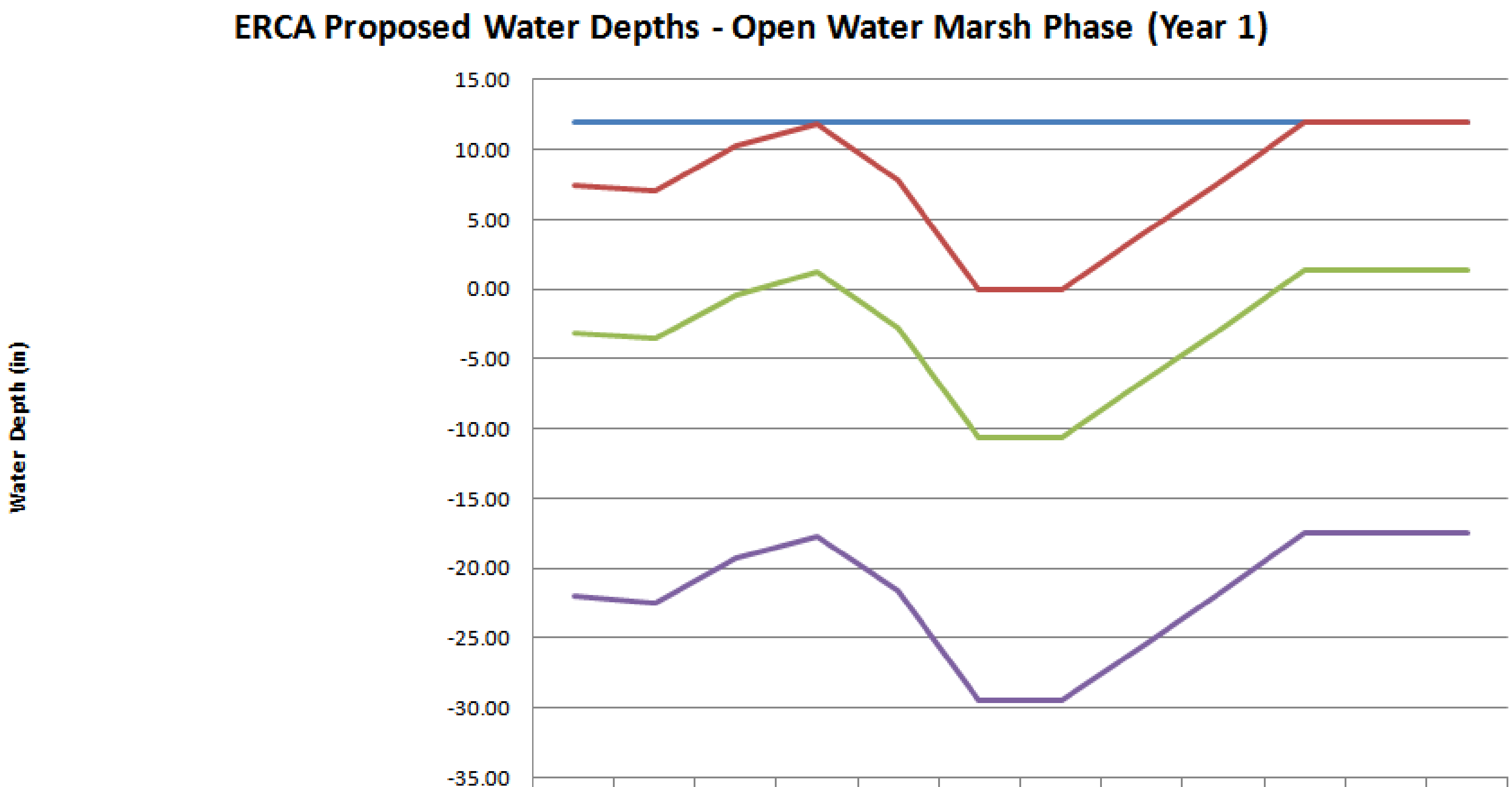
Essex Region Conservation Authority

ERCA Proposed pumping schedule during the open water marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	173.99	173.98	174.06	174.10	174.00	173.80	173.80	173.90	174.00	174.10	174.10	174.10
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.19	0.18	0.26	0.30	0.20	0.00	0.00	0.10	0.20	0.30	0.30	0.30
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	7.48	7.09	10.24	11.81	7.87	0.00	0.00	3.94	7.87	12.00	12.00	12.00
Depth (in) @ 174.07 m GSC (50% area of basin)	-3.15	-3.54	-0.39	1.18	-2.76	-10.63	-10.63	-6.69	-2.76	1.37	1.37	1.37
Depth (in) @ 174.55 m GSC (75% area of basin)	-22.05	-22.44	-19.29	-17.72	-21.65	-29.53	-29.53	-25.59	-21.65	-17.53	-17.53	-17.53
Expected Water Taking by Pumping	No	No	No	Yes	Yes	Yes	No	No	No	Yes	No	No
Direction of Pumping	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	-	-	-	Into Marsh	-	-
Contingency Water Taking by Pumping	-	-	-	-	-	>173.85	>173.85	>174.00	>174.10	>174.20	-	-
Direction of Pumping	-	-	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	173.99	173.98	174.06	174.10	174.00	173.80	173.80	173.90	174.00	174.10	174.10	174.10
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	7.48	7.09	10.24	11.81	7.87	0.00	0.00	3.94	7.87	12.00	12.00	12.00
Depth (in) @ 174.07 m GSC (50% area of basin)	-3.15	-3.54	-0.39	1.18	-2.76	-10.63	-10.63	-6.69	-2.76	1.37	1.37	1.37
Depth (in) @ 174.55 m GSC (75% area of basin)	-22.05	-22.44	-19.29	-17.72	-21.65	-29.53	-29.53	-25.59	-21.65	-17.53	-17.53	-17.53

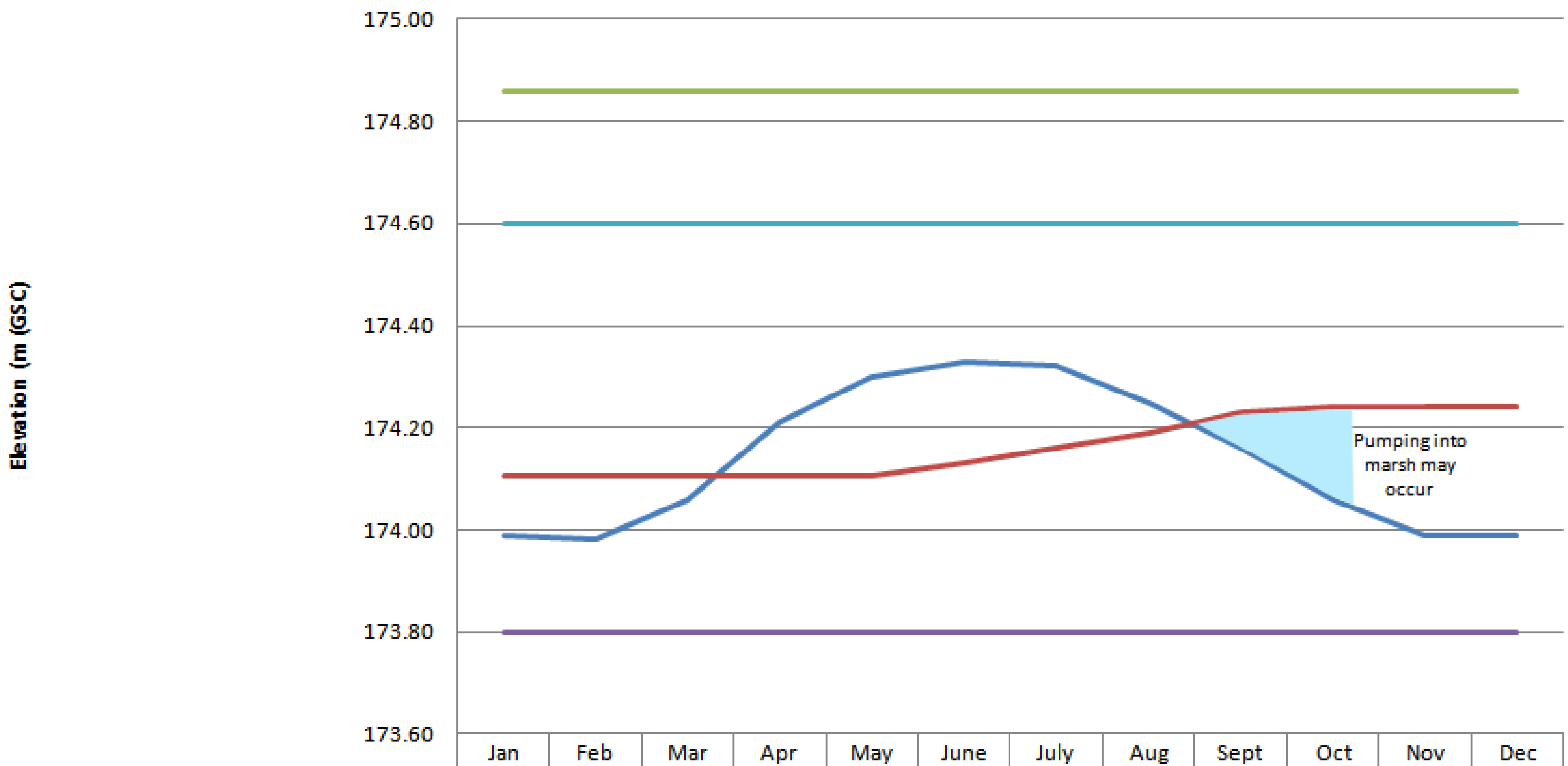
Essex Region Conservation Authority

ERCA Proposed pumping schedule during the open water marsh phase (year 2).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.10	174.10	174.10	174.10	174.10	174.13	174.16	174.19	174.23	174.24	174.24	174.24
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.30	0.30	0.30	0.30	0.30	0.33	0.36	0.39	0.43	0.44	0.44	0.44
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	12.00	12.00	12.00	12.00	12.00	12.99	14.17	15.35	16.93	17.31	17.31	17.31
Depth (in) @ 174.07 m GSC (50% area of basin)	1.37	1.37	1.37	1.37	1.37	2.36	3.54	4.72	6.30	6.69	6.69	6.69
Depth (in) @ 174.55 m GSC (75% area of basin)	-17.53	-17.53	-17.53	-17.53	-17.53	-16.54	-15.35	-14.17	-12.60	-12.21	-12.21	-12.21
Expected Water Taking by Pumping	No	No	No	No	No	No	No	No	Yes	Yes	No	No
Direction of Pumping	-	-	-	-	-	-	-	-	Into Marsh	Into Marsh	-	-
Contingency Water Taking by Pumping	-	-	-	>174.15	>174.15	>174.23	>174.26	>174.29	>174.33	>174.34	-	-
Direction of Pumping	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-

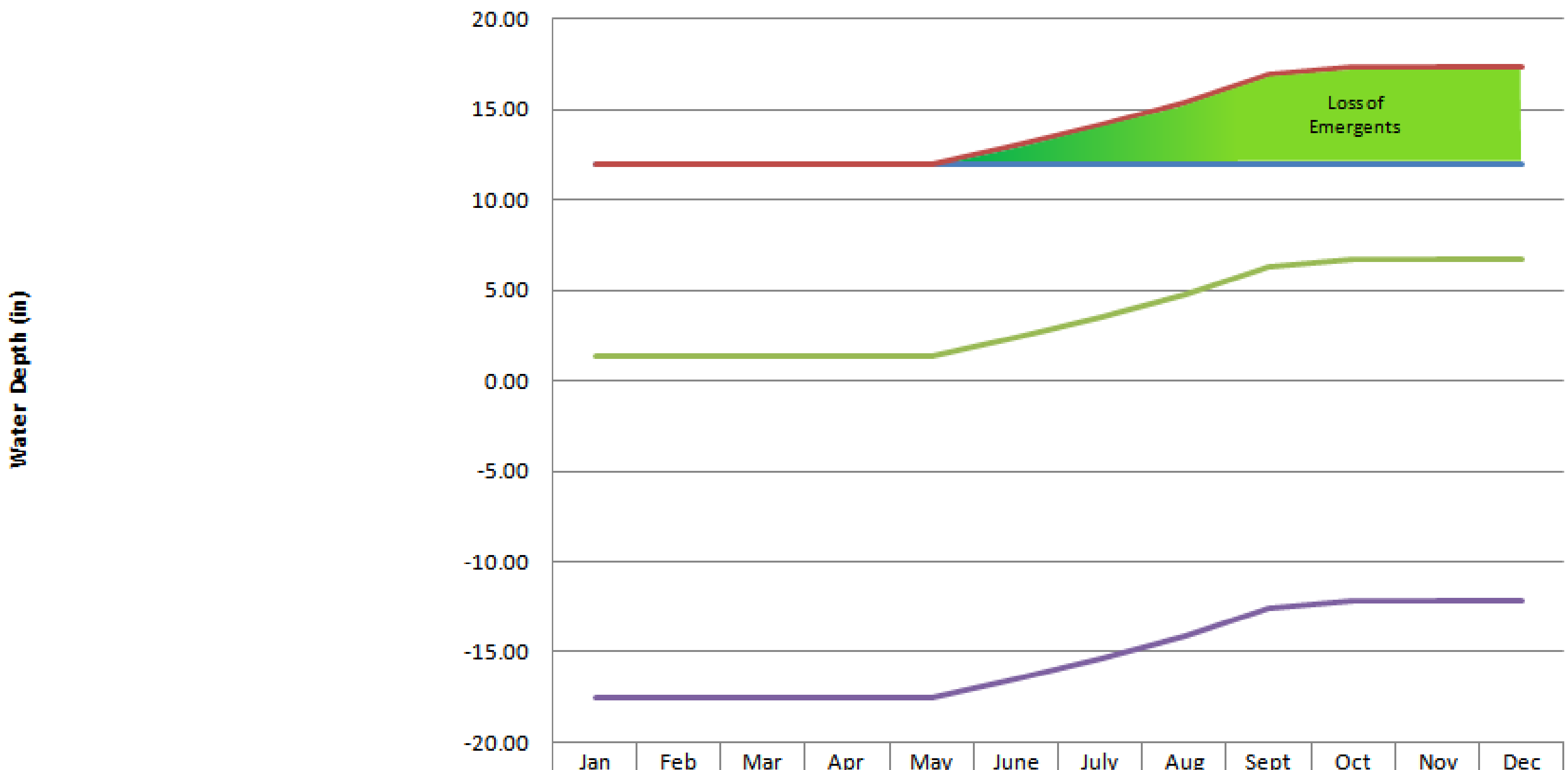
Essex Region Conservation Authority

ERCA Proposed W/L Mgmt. - Open Water Marsh Phase (Year 2)



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.10	174.10	174.10	174.10	174.10	174.13	174.16	174.19	174.23	174.24	174.24	174.24
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60

ERCA Proposed Water Depths - Open Water Marsh Phase (Year 2)

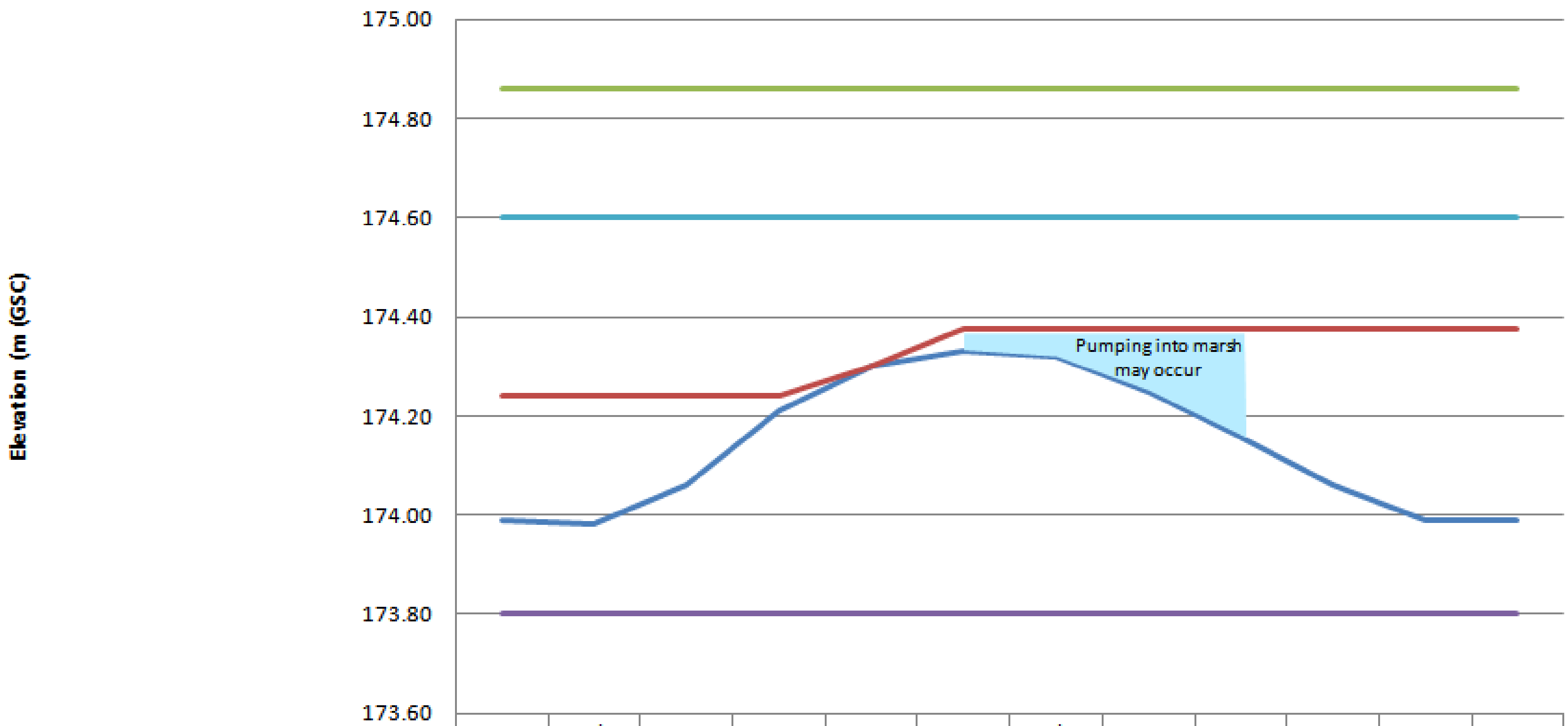


	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	12.00	12.00	12.00	12.00	12.00	12.99	14.17	15.35	16.93	17.31	17.31	17.31
Depth (in) @ 174.07 m GSC (50% area of basin)	1.37	1.37	1.37	1.37	1.37	2.36	3.54	4.72	6.30	6.69	6.69	6.69
Depth (in) @ 174.55 m GSC (75% area of basin)	-17.53	-17.53	-17.53	-17.53	-17.53	-16.54	-15.35	-14.17	-12.60	-12.21	-12.21	-12.21

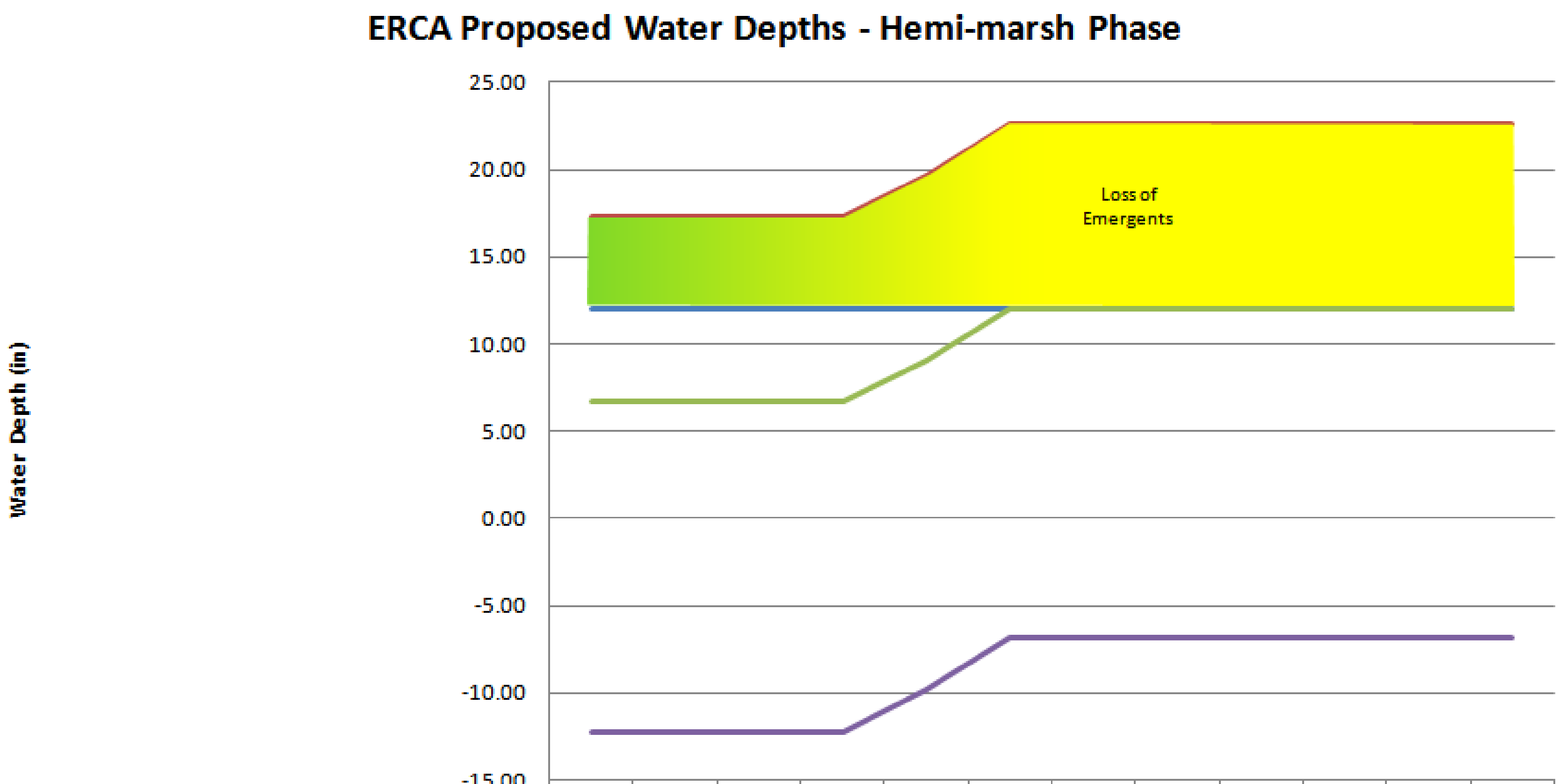
ERCA Proposed pumping schedule during the hemi-marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.24	174.24	174.24	174.24	174.30	174.37	174.37	174.37	174.37	174.37	174.37	174.37
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.44	0.44	0.44	0.44	0.50	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	17.31	17.31	17.31	17.31	19.68	22.63	22.63	22.63	22.63	22.63	22.63	22.63
Depth (in) @ 174.07 m GSC (50% area of basin)	6.69	6.69	6.69	6.69	9.05	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 174.55 m GSC (75% area of basin)	-12.21	-12.21	-12.21	-12.21	-9.85	-6.90	-6.90	-6.90	-6.90	-6.90	-6.90	-6.90
Expected Water Taking by Pumping	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No
Direction of Pumping	-	-	-	-	-	Into Marsh	Into Marsh	Into Marsh	Into Marsh	-	-	-
Contingency Water Taking by Pumping	-	-	-	>174.29	>174.35	>174.47	>174.47	-	-	-	-	-
Direction of Pumping	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-	-	-	-

ERCA Proposed W/L Mgmt. - Hemi-marsh Phase



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.24	174.24	174.24	174.24	174.30	174.37	174.37	174.37	174.37	174.37	174.37	174.37
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	17.31	17.31	17.31	17.31	19.68	22.63	22.63	22.63	22.63	22.63	22.63	22.63
Depth (in) @ 174.07 m GSC (50% area of basin)	6.69	6.69	6.69	6.69	9.05	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 174.55 m GSC (75% area of basin)	-12.21	-12.21	-12.21	-12.21	-9.85	-6.90	-6.90	-6.90	-6.90	-6.90	-6.90	-6.90

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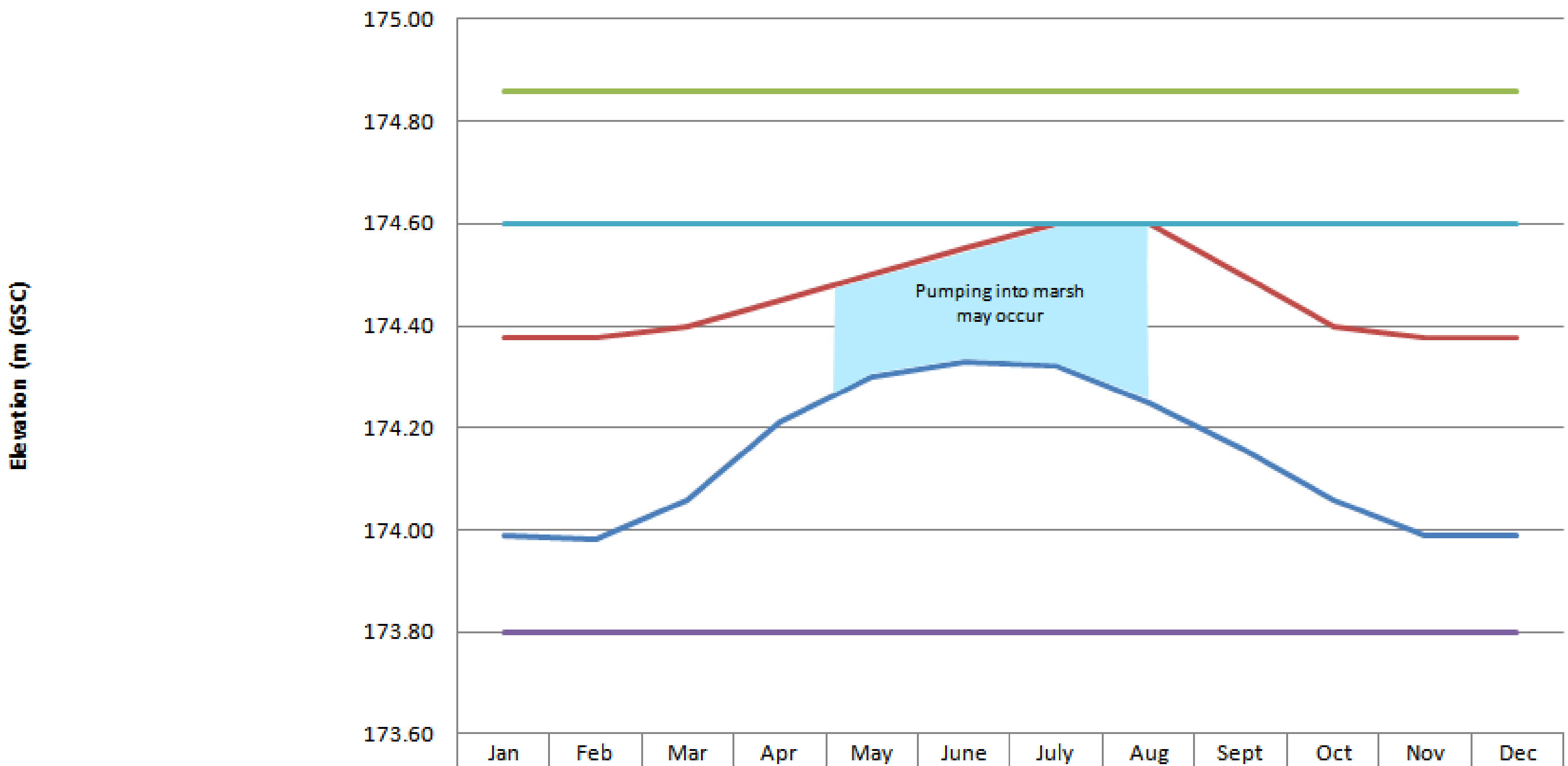
ERCA Proposed pumping schedule during the overgrown marsh phase.

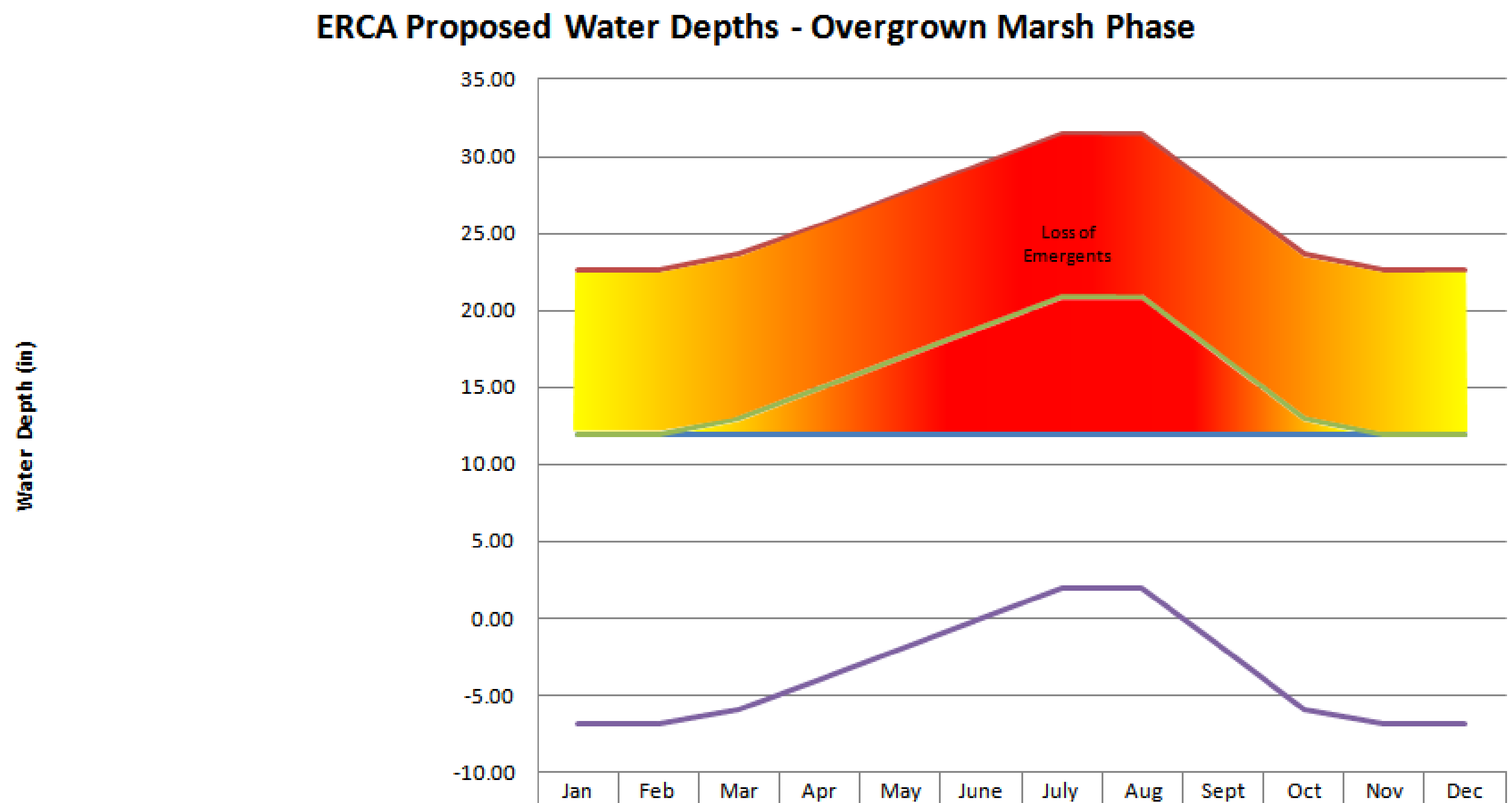
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.37	174.37	174.40	174.45	174.50	174.55	174.60	174.60	174.50	174.40	174.37	174.37
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60
Target Marsh Depths [Above Basin Elevation of 173.80 m GSC] (m)	0.57	0.57	0.60	0.65	0.70	0.75	0.80	0.80	0.70	0.60	0.57	0.57
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	22.63	22.63	23.62	25.59	27.56	29.53	31.50	31.50	27.56	23.62	22.63	22.63
Depth (in) @ 174.07 m GSC (50% area of basin)	12.00	12.00	12.99	14.96	16.93	18.90	20.87	20.87	16.93	12.99	12.00	12.00
Depth (in) @ 174.55 m GSC (75% area of basin)	-6.90	-6.90	-5.91	-3.94	-1.97	0.00	1.97	1.97	-1.97	-5.91	-6.90	-6.90
Expected Water Taking by Pumping	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Direction of Pumping	-	-	-	-	Into Marsh	Into Marsh	Into Marsh	Into Marsh	-	-	-	-
Contingency Water Taking by Pumping	-	-	-	≥174.60	≥174.60	≥174.60	≥174.60	≥174.60	≥174.60	≥174.60	-	-
Direction of Pumping	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-

ERCA Proposed W/L Mgmt. - Overgrown Marsh Phase

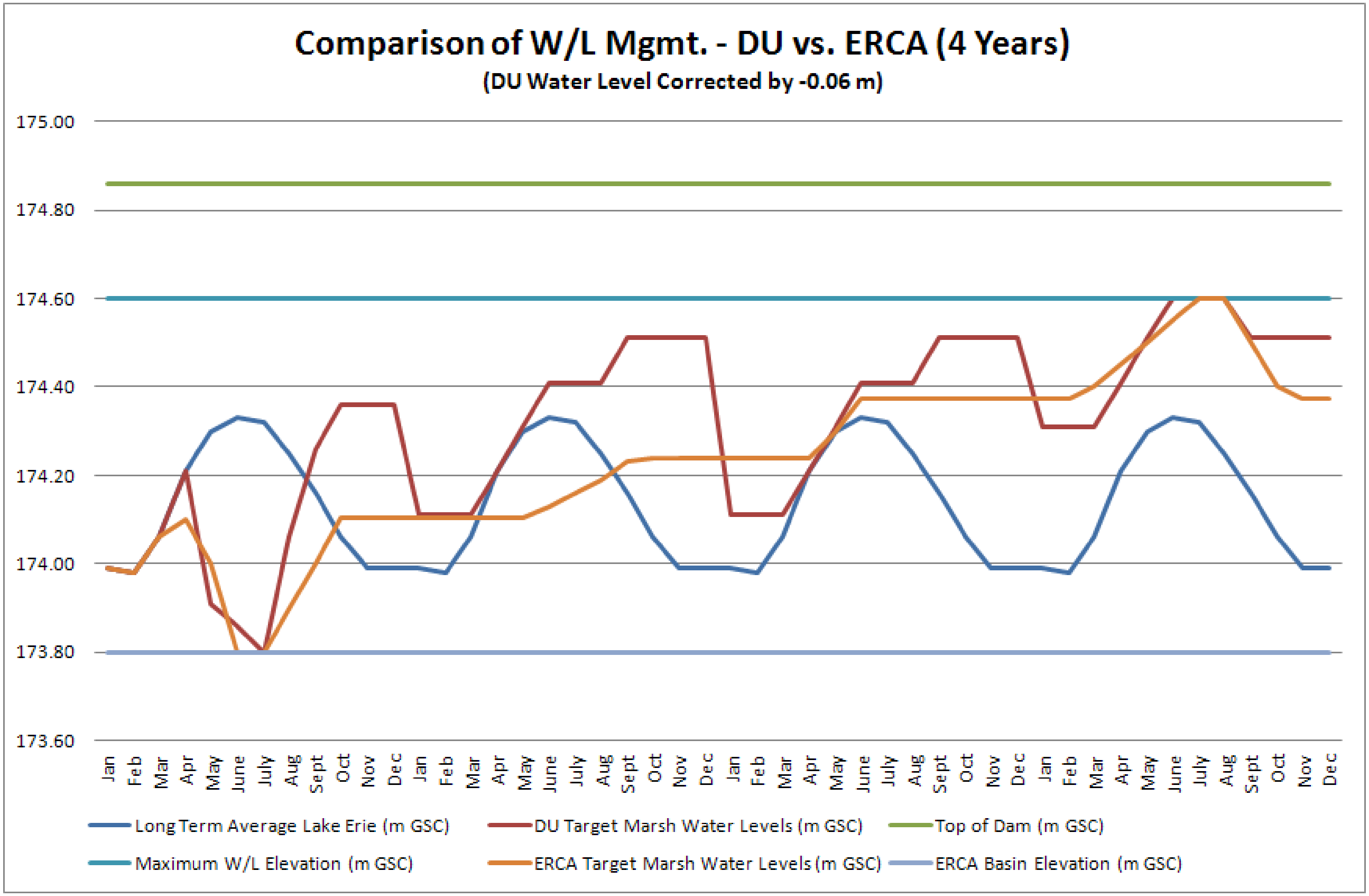


	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m GSC)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m GSC)	174.37	174.37	174.40	174.45	174.50	174.55	174.60	174.60	174.50	174.40	174.37	174.37
Top of Dam (m GSC)	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86	174.86
Basin Elevation (m GSC)	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80	173.80
Maximum W/L Elevation (m GSC)	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60	174.60

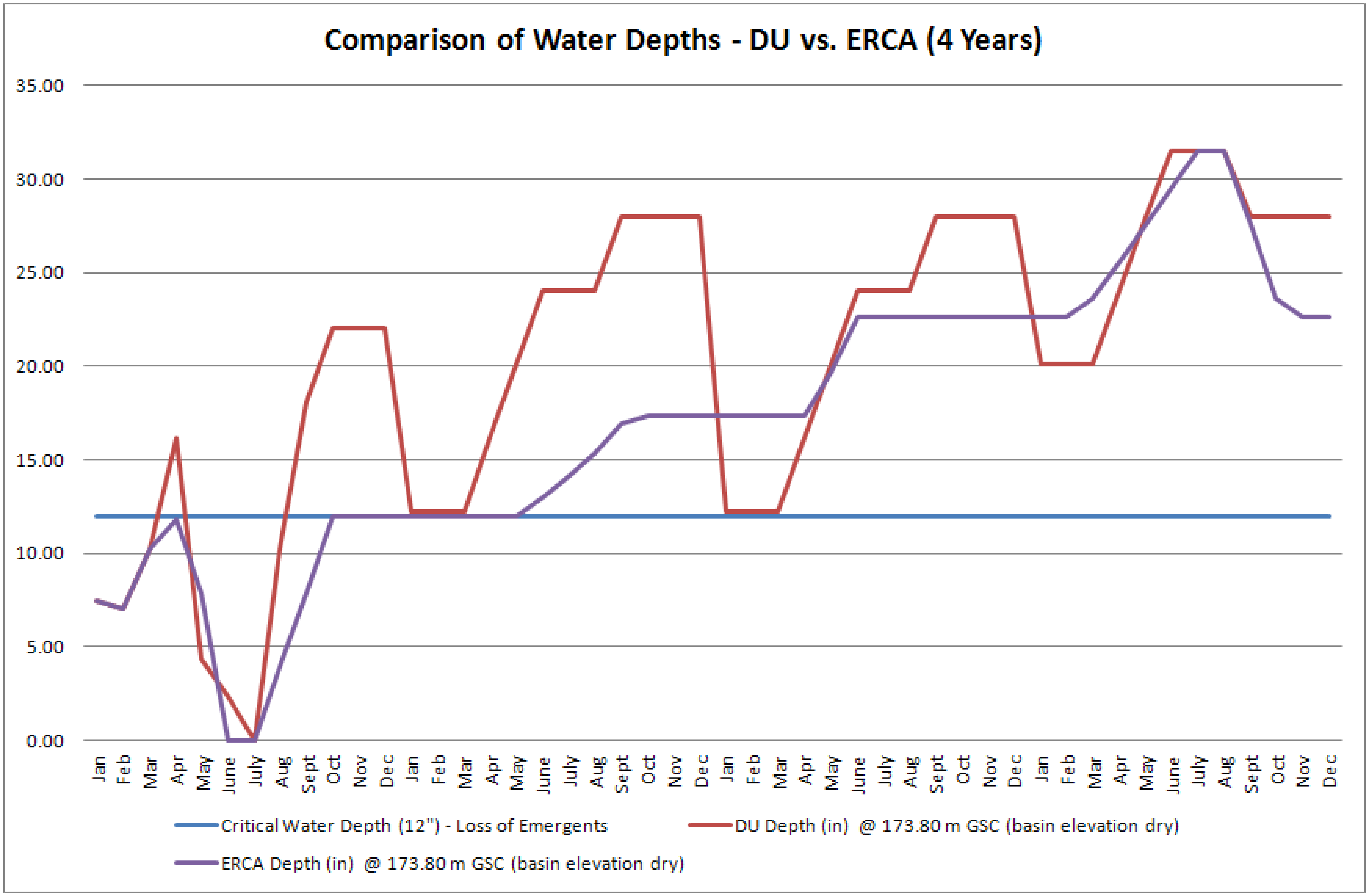
Essex Region Conservation Authority

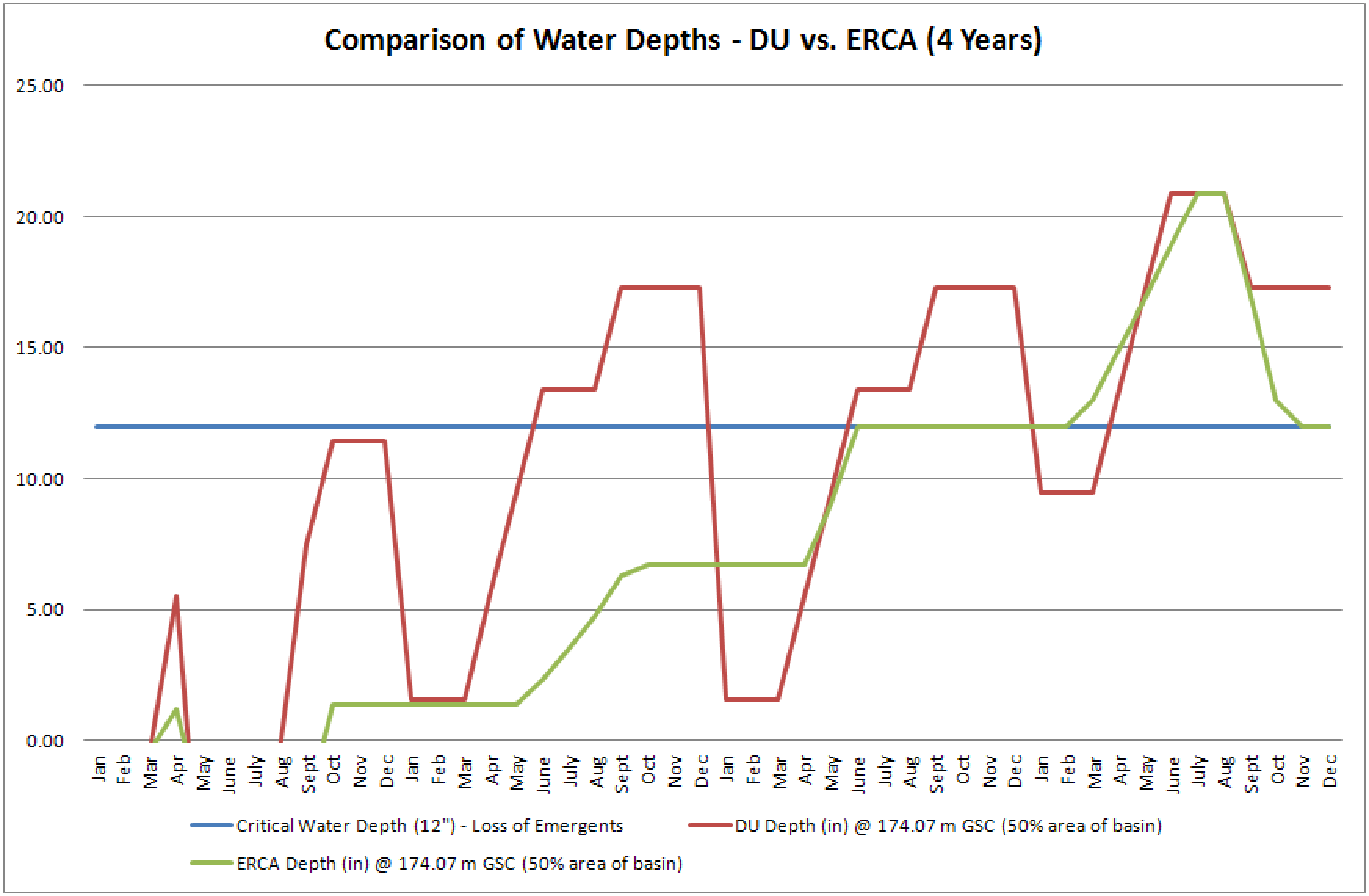


	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Water Depth (12") - Loss of Emergents	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Depth (in) @ 173.80 m GSC (basin elevation dry)	22.63	22.63	23.62	25.59	27.56	29.53	31.50	31.50	27.56	23.62	22.63	22.63
Depth (in) @ 174.07 m GSC (50% area of basin)	12.00	12.00	12.99	14.96	16.93	18.90	20.87	20.87	16.93	12.99	12.00	12.00
Depth (in) @ 174.55 m GSC (75% area of basin)	-6.90	-6.90	-5.91	-3.94	-1.97	0.00	1.97	1.97	-1.97	-5.91	-6.90	-6.90



Comparison of W/L Mgmt. - DU vs. ERCA (4 Years)
(DU Water Level Corrected by -0.06 m)
175.00
174.80
174.60
174.40
174.20
174.00
173.80
173.60
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Long Term Average Lake Erie (m GSC)
DU Target Marsh Water Levels (m GSC)
Top of Dam (m GSC)
Maximum W/L Elevation (m GSC)
ERCA Target Marsh Water Levels (m GSC)
ERCA Basin Elevation (m GSC)


Comparison of Water Depths - DU vs. ERCA (4 Years)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Critical Water Depth (12") - Loss of Emergents
DU Depth (in) @ 173.80 m GSC (basin elevation dry)
ERCA Depth (in) @ 173.80 m GSC (basin elevation dry)


Comparison of Water Depths - DU vs. ERCA (4 Years)
25.00
20.00
15.00
10.00
5.00
0.00
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Critical Water Depth (12") - Loss of Emergents
DU Depth (in) @ 174.07 m GSC (50% area of basin)
ERCA Depth (in) @ 174.07 m GSC (50% area of basin)

Appendix

Ducks Unlimited Canada

2007 Big Creek Marsh Water Pumping Operations Plan for Creekside Hunting and Fishing Club

BIG CREEK MARSH
WATER PUMPING OPERATIONS PLAN
for
CREEKSIDE HUNTING AND FISHING CLUB

Permit to Take Water 0081-6JNPJ5
Reference Number 8700-6E7N8X

Prepared by
Ducks Unlimited Canada
1-614 Norris Court
Kingston, Ontario K7P 2R9
Tel: (613) 389-0418
Fax: (613) 389-0239

January 2007

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1.0 INTRODUCTION

1.1. PURPOSE

The purpose of this water pumping operations plan is to establish a science-based water taking schedule by means of pumping that will augment the natural water level regime of Big Creek Marsh and optimize both the habitat conservation values of this ecosystem for breeding and staging waterfowl and other wildlife and the social values derived from this coastal wetland, as regulated by Permit to Take Water Number 0081-6JNPJ5.

1.2. PERMIT TO TAKE WATER

Permit Number: 0081-6JNPJ5
Reference Number: 8700-6E7N8X
Permit Holder: Creekside Hunting and Fishing Club
Expiry: March 31, 2007

Pumping into Big Creek Marsh
Maximum Water Taking per Minute: 81,828 L (pumps 1 & 2 combined)
Maximum Water Taking per Day: 88,374,240 L
Maximum Number of Days per Year: 60

Pumping out of Big Creek Marsh
Maximum Water Taking per Minute: 81,828 L (pumps 1 & 2 combined)
Maximum Water Taking per Day: 88,374,240 L
Maximum Number of Days per Year: 60

This permit only regulates the taking of water by pumping and not by the dam structure.

1.3. QUALIFIED PERSON

This water pumping operations plan was developed by a Qualified Person for Category 2 Surface Water Takings as defined in Schedule 3.

Qualified Person Contact Information
Scott Muir (B.Sc.)
Ducks Unlimited Canada
1-614 Norris Court
Kingston, Ontario K7P 2R9
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Email: s_muir@ducks.ca

1.4. CONSULTATION

As per Condition 3.6 (b), consultation occurred during the preparation of this plan with experts / knowledgeable persons from the Ministry of Natural Resources (Chatham Area Office), the Essex Region Conservation Authority, the Ministry of Natural Resources, the Department of Fisheries and Oceans, the Town of Amherstburg Advisory Committee on the Environment and the Big Creek Association. A summary of each consultation meeting is included in Appendices A and B.
1 and 2

2.0 WATER TAKING BY PUMPING

2.1 BACKGROUND

Big Creek Marsh is a 682.3-ha (1,686-acre) lacustrine/riverine wetland located east of the confluence of the Detroit River and Lake Erie at the extreme southwestern tip of Ontario. This wetland offers significant value to waterfowl, waterbirds and other wetland dependent species because of its immense size and strategic location, benefiting from the funneling effect of the Great Lakes shoreline and the convergence of the Mississippi and Atlantic flyways. This marsh not only provides critical habitat for breeding and staging waterfowl, but also for a wide array of other wildlife, plants and fish. The site has been designated a Provincially Significant Wetland by the Ontario Ministry of Natural Resources and a Globally Significant Important Bird Area by BirdLife International, and migratory waterfowl surveys by the Canadian Wildlife Service (CWS) revealed that this wetland historically supported the highest waterfowl use days per hectare in the province.

Southwestern Ontario has seen some of the highest wetland loss of any area in the province, which only serves to elevate the importance of remaining habitats like Big Creek Marsh. In fact, the majority of the remaining wetlands along the Detroit River and the western end of Lake Erie continue to exist and function to their full potential because of the commitment made by sportsmen toward their preservation and ongoing management. Active management of these remaining marshes has become crucial in order to satisfy the breeding and migratory needs of various coastal wetland dependent wildlife species.

The basin of Big Creek Marsh is extremely flat having only a 0.13 m elevation difference between County Road 20 and the outlet dam at the mouth of Big Creek, a distance of more than 4.0 km, although some slightly deeper isolated pockets also exist. It receives runoff from a 6,813-ha (16,834-acre) watershed that includes numerous agricultural drainage ditches.

Big Creek Marsh is a regulated system having a rudimentary control dam at its outlet to Lake Erie. The dam was originally constructed in 1909 but was refurbished in 1998 by the previous owners. This control dam can theoretically regulate water levels in the marsh between 173.86 m and 174.86 m (IGLD 1985) through the manipulation of guillotine plates. Despite the presence of the dam, its functionality is largely influenced by Lake Erie water levels, which tend to peak in June/July (long term average – 174.33 m IGLD 1985) and then decline to annual lows in December/January/February (long-term average – 173.98 m IGLD 1985). Because of these seasonal variations in the annual water level regime of Lake Erie, the dam structure is limited in its ability to effectively manage the water levels within the marsh and as such, pumping has been an integral part of actively managing the vegetation and water levels of Big Creek Marsh since 1909.

The Permit Holder acquired the property in 2003 and is the major landowner along this system owning various land parcels totaling 1,012 ha (2,500 ac), including approximately 364 ha (900 ac) of Big Creek Marsh and its associated dam and pumping infrastructure. The Permit Holder is committed to maintaining pumping infrastructure for wetland habitat conservation purposes and recently replaced the existing diesel-powered pumps in 2006 with more environmentally-friendly electric pumps.

3.0 PROPOSED WATER PUMPING OPERATIONS PLAN

3.1 PLAN FORMAT

Given wetland losses in the extreme south-western region of Ontario since the turn of the century and the continuing pressures and impairments being faced by remaining marshes from excessive nutrient and sediment loading, chemicals, exotic species and hydrological changes in Lake Erie water levels, active management has become essential in satisfying the breeding and migratory needs of the various coastal wildlife species that are reliant on these habitats. Big Creek Marsh like most of the other coastal wetlands in this area has dam and pumping infrastructure that affords it greater water level management flexibility than unregulated systems. Although the outlet dam offers some water level management flexibility, pumping is essential in order to augment the hydrology of Big Creek Marsh and ultimately optimize both the ecological and social values of this site.

Wetlands are highly dynamic habitats whose overall productivity and nutrient budgets are driven by the plants found within them. Site specific hydrology determines the establishment and rate of change of these macrophytic communities and as such, pumping will be largely guided by the abundance and distribution of the emergent plant communities found in Big Creek Marsh.

With the abundance of emergent vegetation, the proportion of emergent vegetation to open water and the dominant hydrophytic plant species being the key habitat indicators guiding wetland management and pumping decisions of the Permit Holder, different pumping schedules have been developed based on different wetland physiognomies. The potential pumping requirements discussed in this water pumping operations plan were developed based on long-term average hydrological data for the area. Specific pumping requirements may change in response to variations in Lake Erie water levels and extreme seasonal weather events.

i. Hemi marsh (> 30% or < 70% emergent vegetation cover)
ii. Open water marsh (≤ 30% emergent vegetation cover)
iii. Overgrown marsh (≥ 70% emergent vegetation cover)

Findings from the hydrological analysis and the hydraulic analysis of the pumping infrastructure are presented in Tables 1, 2 and 3 and will further guide water taking activities under the terms and conditions of the PTTW, in order to achieve target water levels for the purpose of wetland conservation.

3.2 PUMPING PLAN – HEMI MARSH CONDITION

3.2.1 RATIONALE

The hemi marsh condition is frequently considered the most productive phase of a freshwater temperate marsh, as it generally supports the greatest diversity of floral and faunal communities. This wetland phase is typically characterized as having an emergent vegetation component of between 30 and 70 percent, with 50 percent being considered optimum, as it affords excellent cover from predators, as well as quality plant and macroinvertebrate food resources for staging, breeding, moulting and fledging waterfowl and waterbirds, as well as for other wetland dependent species.

Vegetative communities tend to be dominated by a mix of perennial emergent and submergent plants that have established over time along a water-depth gradient. Well-established robust hydrophytes will grow and propagate vegetatively under flooded conditions during the spring and summer months but become senescent during the fall and winter months.

3.2.2 EXPECTED WATER TAKING REQUIREMENTS

3.2.2.1 PUMPING OUT OF BIG CREEK MARSH

Pumping out of the marsh will likely not be required during the year except possibly in cases of sustained precipitation or severe storm events that result in marsh water levels exceeding 174.50 m (IGLD 1985) or greater during the late spring or early summer periods for extended periods of time, as plants are extremely susceptible to injury or death. During this period of growth, emergent plants are producing new leaves and are drawing heavily on carbohydrate reserves stored in their rhizomes from the previous growing season. At the point where these energy stores have been depleted and the plant begins to photosynthesize, excessively deep water can quickly result in plant mortality and loss from the site. During the hemi marsh scenario, pumping out of Big Creek Marsh for habitat conservation purposes will not normally be required.

3.2.2.2 PUMPING INTO BIG CREEK MARSH

Pumping into the marsh is likely to occur during the summer (June, July and August) to early fall (September) period in order to compensate for declines in marsh water levels resulting from summer evapotranspiration losses and to also achieve the target water level of 174.50 m, which will optimize the habitat quality for fall migrating waterfowl. During the hemi marsh scenario, pumping from Lake Erie into Big Creek Marsh for habitat conservation purposes is estimated to require approximately 42% of the maximum allowable water taking amount in PTTW #0081-6JNPJ5. Refer to Table 4 and Graph 1.

3.3 PUMPING PLAN – OPEN WATER MARSH CONDITION

3.3.1 RATIONALE

A lack of emergent perennial plants throughout the wetland basin (less than 30 percent of the wetland area) is characteristic of an open water marsh and signals the onset of the final degenerating stage in the life-cycle of a marsh. This elimination of vegetation is typically the result of prolonged deep flooding at levels that exceed long-term tolerance ranges and hinder oxygen transport from the aerial part of the plant to their root systems, excessive herbivory or disease. During this phase, wetland productivity is considered to be at its lowest, as the habitat no longer satisfies the life history requirements of many wetland-dependent species. This lack of emergent cover coupled with declines in seeds and macroinvertebrate densities tends to negatively affect the usage of the site by waterfowl, waterbirds and other wetland dependent wildlife. A decline in the mean aboveground biomass of the emergent plants also translates into a reduction in the belowground biomass, which greatly impairs the ability of the remaining plants to propagate vegetatively. The large-scale revegetation of an open water marsh is only possible through a short term (May to August) dewatering of the site, either naturally or by active management because wetland seedbanks cannot germinate under flooded conditions, as they require aerobic conditions. There is no set rule as to the optimal frequency of a drawdown because it depends on many site-specific factors and logistical considerations but it can range from once in a seven-year period to once in a twenty-five year period.

The pumping infrastructure can facilitate the restoration of vegetative structural diversity to the site by expediting the controlled removal of water from the wetland basin so that a sufficient growing window is available to enable the viable dormant seeds of various macrophytes to germinate and become established throughout the basin. The concept of a managed drawdown is a widely-practiced, scientifically-supported wetland management technique for restoring marsh productivity and biodiversity and should be considered when less than 30 percent of the wetland is comprised of emergent vegetation.

3.3.2 EXPECTED WATER TAKING REQUIREMENTS

3.3.2.1 PUMPING OUT OF BIG CREEK MARSH

Given that long-term average water levels for Lake Erie during the growing season (April to early-August) are higher than the average basin elevation of Big Creek Marsh (174.86 m IGLD 1985), pumping will normally be required to facilitate a complete controlled drawdown of the site. Successfully re-establishing emergent hydrophytes requires an early-season drawdown with the removal of all standing water from Big Creek Marsh being completed by early-June so as to ensure successful germination of the existing seedbank and an adequate growing window for shoot development. This undertaking should commence after the spring runoff has passed and early season rains have subsided (typically mid-late April) and will initially involve pumping water out of the marsh that could not be free-flowed through the dam structure. Additional pumping is also likely to be required throughout spring/summer, in order to remove any water pooling from extreme rain events and maintain the site in a condition that will promote seedling growth. During the open water marsh scenario, pumping from Big Creek Marsh into Lake Erie for habitat conservation purposes is estimated to require approximately 52% of the maximum allowable water taking amount in PTTW #0081-6JNPJ5. Refer to Table 5 and Graph 2.

3.3.2.2 PUMPING INTO BIG CREEK MARSH

Reflooding of the newly vegetated marsh, which will be comprised of newly recruited mudflat annuals and emergent species should be conducted systematically in stages so as to maximize the vegetative response. Upon reflooding, annual species will be eliminated, emergent species will expand vegetatively and submergents will begin to germinate. Depending upon the plant species and their stages of development, water levels in the marsh during this reflooding should likely not exceed 174.35 m (IGLD 1985). Because much of the mid to late summer reflooding can be accomplished by free flowing water through the dam structure from Lake Erie into Big Creek Marsh, pumping into the marsh will likely only be required in late summer / early fall in order to increase water depths to the target level of 174.35 m (IGLD 1985), as this level exceeds that of Lake Erie during this period. During the open water marsh scenario, pumping from Lake Erie into Big Creek Marsh for habitat conservation purposes is estimated to require approximately 26% of the maximum allowable water taking amount in PTTW #0081-6JNPJ5. Refer to Table 5 and Graph 2.

3.4 PUMPING PLAN – OVERGROWN MARSH CONDITION

3.4.1 RATIONALE

Because of the relatively uniform relief of the Big Creek Marsh basin, there exists the possibility of dense monotonous stands of emergent vegetation becoming established, which could also reduce the overall attractiveness of the site for waterfowl and other waterbirds. A ratio of emergent vegetation to open water exceeding 70 percent will probably necessitate an increase in water levels in order to suppress the further expansion of plant communities and to drown out some of the existing dense vegetation, so that more open water pockets are created.

3.4.2 EXPECTED WATER TAKING REQUIREMENTS

3.4.2.1 PUMPING OUT OF BIG CREEK MARSH

Pumping out of the marsh will typically not be required during any time of the year, as the goal is to maintain deep water conditions. Holding water at a target level of 174.60 m (IGLD 1985) would reduce the amount of freeboard to the top of the dam structure, so sustained precipitation or severe storm events could cause water levels to rise and potentially compromise the integrity of the structure. In this case, it may be advantageous to augment the free-flowing of excess water through the dam with pumping in order to hasten its passage and safeguard the infrastructure. During the overgrown marsh scenario, pumping from Big Creek Marsh into Lake Erie for habitat conservation purposes will not normally be required.

3.4.2.2 PUMPING INTO BIG CREEK MARSH

Pumping into the marsh will likely be required to increase water levels to depths that will cause the controlled die-off of select vegetation. A target water level of approximately 174.60 m (IGLD 1985) should be achieved by mid-June and maintained throughout the summer growing months, in order to cause plant stress and eventual death by hindering the transportation of oxygen by plants from their aerial shoots to their roots. Additional pumping is likely to be required in order to maintain this target water level and compensate for cumulative summer water losses due to evapotranspiration. During the overgrown marsh scenario, pumping from Lake Erie into Big Creek Marsh for habitat conservation purposes is estimated to require approximately 64% of the maximum allowable water taking amount in PTTW #0081-6JNPJ5. Refer to Table 6 and Graph 3.

4.0 PLAN REVIEW

The Permit Holder and the Qualified Person will annually assess the wetland habitat indicators to determine the appropriate pumping prescription for implementation. In the event that the habitat indicators trigger the open water marsh pumping plan, notification and consultation with regulatory agencies and abutting landowners would be undertaken prior to any implementation, in order to educate, identify and address any concerns or issues.

4.1 ADAPTIVE MANAGEMENT

Underpinning the pumping prescription will be the concept of Adaptive Management, which can be described as managing in the face of uncertainty with a focus on its reduction. Traditional management practices will be merged with scientifically-supported wetland principles and management techniques. Resultant habitat responses will be constantly monitored and measured against predicted results with

Table 1. Average Monthly Water Budget for Big Creek Marsh

Month	Average % Evapotranspiration Loss	Average Evapotranspiration Loss (mm)	Average Precipitation (mm)	Average Net Water Balance (mm)
January	0	0.0	62.5	+62.5
February	0	0.0	59.0	+59.0
March	0	0.0	78.1	+78.1
April	5	30.0	83.0	+53.0
May	12	72.0	73.7	+ 1.7
June	20	120.0	82.4	-37.6
July	23	138.0	75.9	-62.1
August	17	102.0	80.5	-21.5
September	14	84.0	86.2	+ 2.2
October	8	48.0	63.7	+15.7
November	1	6.0	76.4	+70.4
December	0	0.0	73.0	+73.0
TOTAL	100	600.0	894.4	+294.4

Table 2. Impact of Storm Events on Big Creek Marsh Water Levels

Storm Event	Rainfall (mm)	Direct runoff (mm)	Associated Increase in Big Creek Marsh Water Levels (m)
Q2	49.2	14.4	0.14
Q5	63.0	21.5	0.22
Q10	72.7	27.5	0.28
Q25	86.0	35.5	0.36
Q50	94.0	41.8	0.42
Q100	100.0	49.8	0.50

Table 3. Big Creek Marsh pumping infrastructure hydraulics

Pumping Capacity (combined pumps 1 & 2): 60,560 L/min
Maximum Water Taking / day as per PTTW 0081-6JNPJ5: 88,374,240 L
Maximum Allowable Water Taking / year[1]: 5,302,454,400 L

Change in Water Depth in Wetland Impoundment (m)	Pumping Time Required to Raise or Lower Water Level in Wetland Impoundment (days)	% of Total Water Taking Allowed in PTTW #0081-6JNPJ5
0.00	0	0
0.05	3.91	6.4
0.10	7.82	12.9
0.15	11.73	19.3
0.20	15.64	25.7
0.25	19.55	32.2
0.30	23.46	38.6
0.35	27.37	45.0
0.40	31.28	51.4
0.45	35.19	57.9
0.50	39.10	64.3
0.55	43.01	70.7
0.60	46.92	77.2
0.65	50.83	83.6
0.70	54.74	90.0
0.75	58.65	96.5
0.77	60.00	100.0

[1] 1 year = 60 days

= 60-day pumping maximum

Table 4. Proposed pumping schedule during the hemi-marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m)	174.10	174.10	174.10	174.21	174.30	174.40	174.40	174.40	174.50	174.50	174.50	174.50
Target Marsh Depths (m)	0.25	0.25	0.25	0.35	0.45	0.55	0.55	0.55	0.65	0.65	0.65	0.65
Expected Water Taking by Pumping	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No
Direction of Pumping	-	-	-	-	-	Into Marsh	Into Marsh	Into Marsh	Into Marsh	-	-	-
Contingency Water Taking by Pumping	-	-	-	-	>174.50	>174.50	>174.50	-	-	-	-	-
Direction of Pumping	-	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	-	-	-	-	-

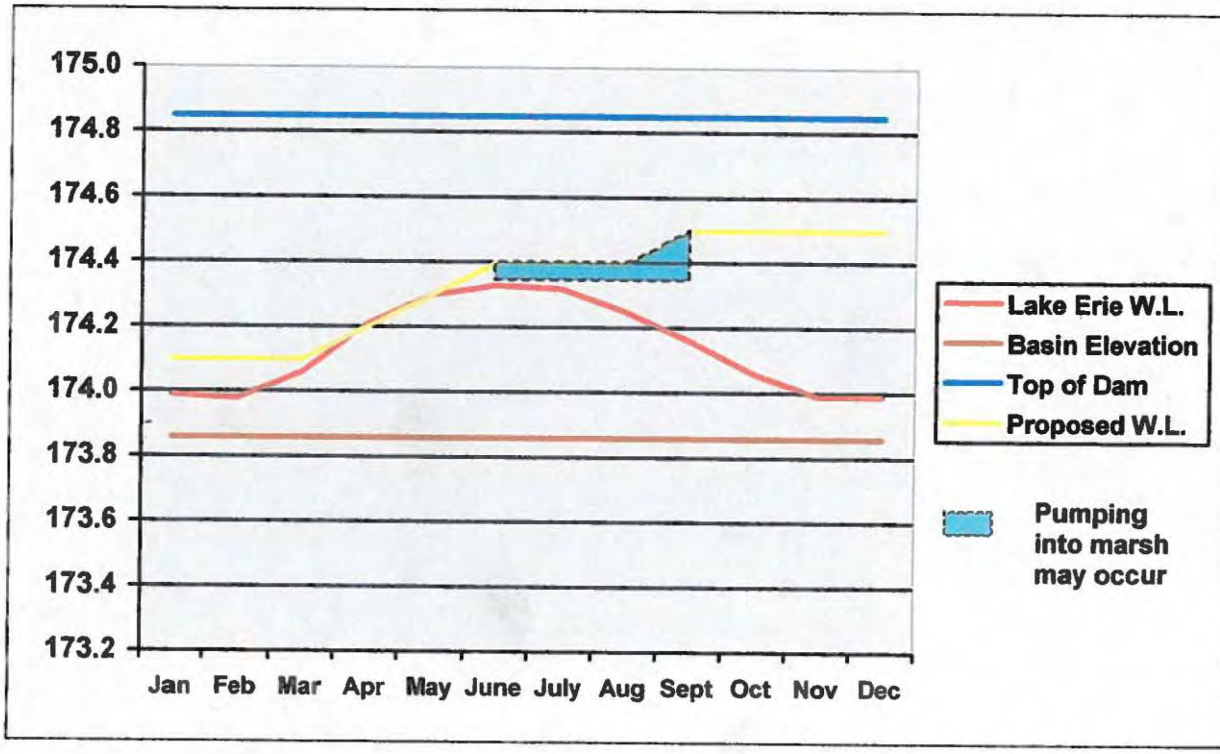
Table 5. Proposed pumping schedule during the open water marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m)	173.99	173.98	174.06	174.21	173.90	173.86	173.86	174.05	174.25	174.35	174.35	174.35
Target Marsh Depths (m)	0.13	0.12	0.20	0.15	0.05	0.00	0.00	0.20	0.40	0.50	0.50	0.50
Expected Water Taking by Pumping	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No
Direction of Pumping	-	-	-	Out of marsh	Out of marsh	Out of Marsh	-	-	Into Marsh	Into Marsh	-	-
Contingency Water Taking by Pumping	-	-	-	-	-	>173.90	>173.90	>174.15	>174.35	>174.45	-	-
Direction of Pumping	-	-	-	-	-	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-

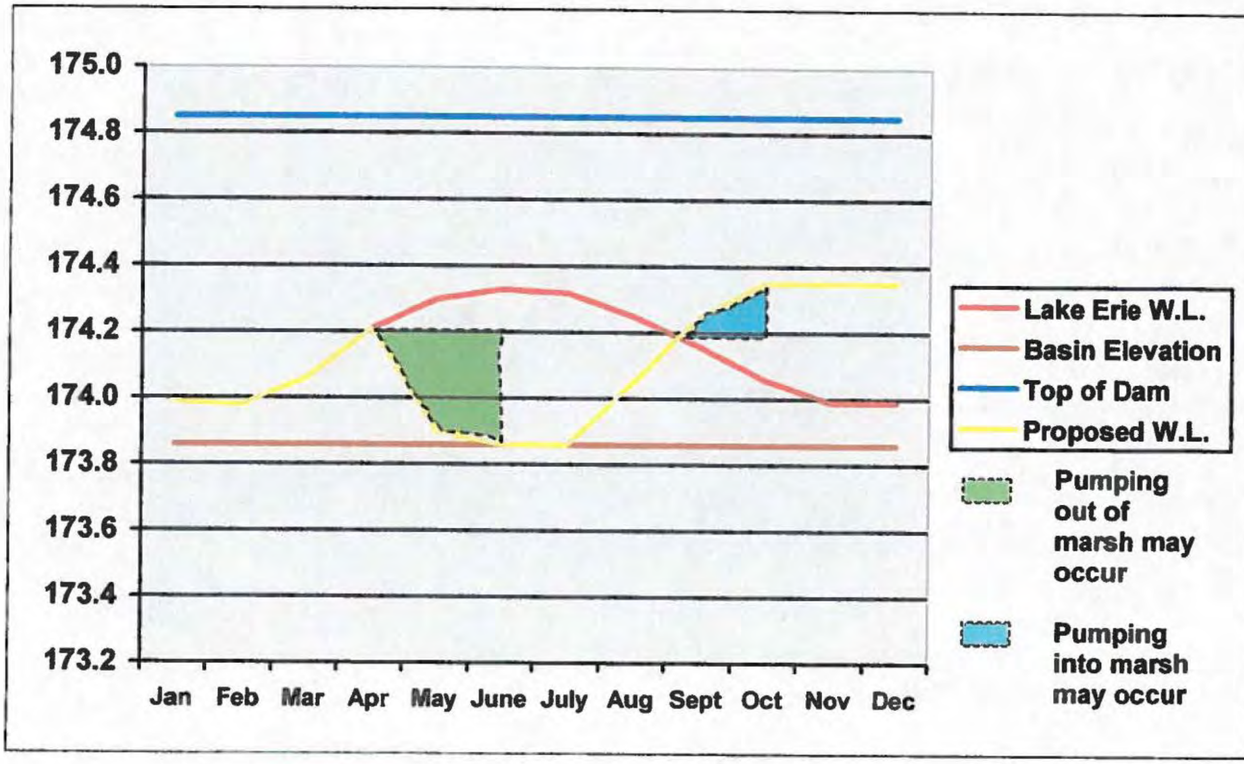
Table 6. Proposed pumping schedule during the overgrown marsh phase.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Long Term Average Lake Erie (m)	173.99	173.98	174.06	174.21	174.30	174.33	174.32	174.25	174.16	174.06	173.99	173.99
Target Marsh Water Levels (m)	174.30	174.30	174.30	174.40	174.50	174.60	174.60	174.60	174.50	174.50	174.50	174.50
Target Marsh Depths (m)	0.45	0.45	0.45	0.55	0.65	0.75	0.75	0.75	0.65	0.65	0.65	0.65
Expected Water Taking by Pumping	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Direction of Pumping	-	-	-	-	Into Marsh	Into Marsh	Into Marsh	Into Marsh	-	-	-	-
Contingency Water Taking by Pumping	-	-	-	≥174.60	≥174.60	≥174.70	≥174.70	≥174.70	≥174.60	≥174.60	-	-
Direction of Pumping	-	-	-	Out of Marsh	Out of marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	Out of Marsh	-	-

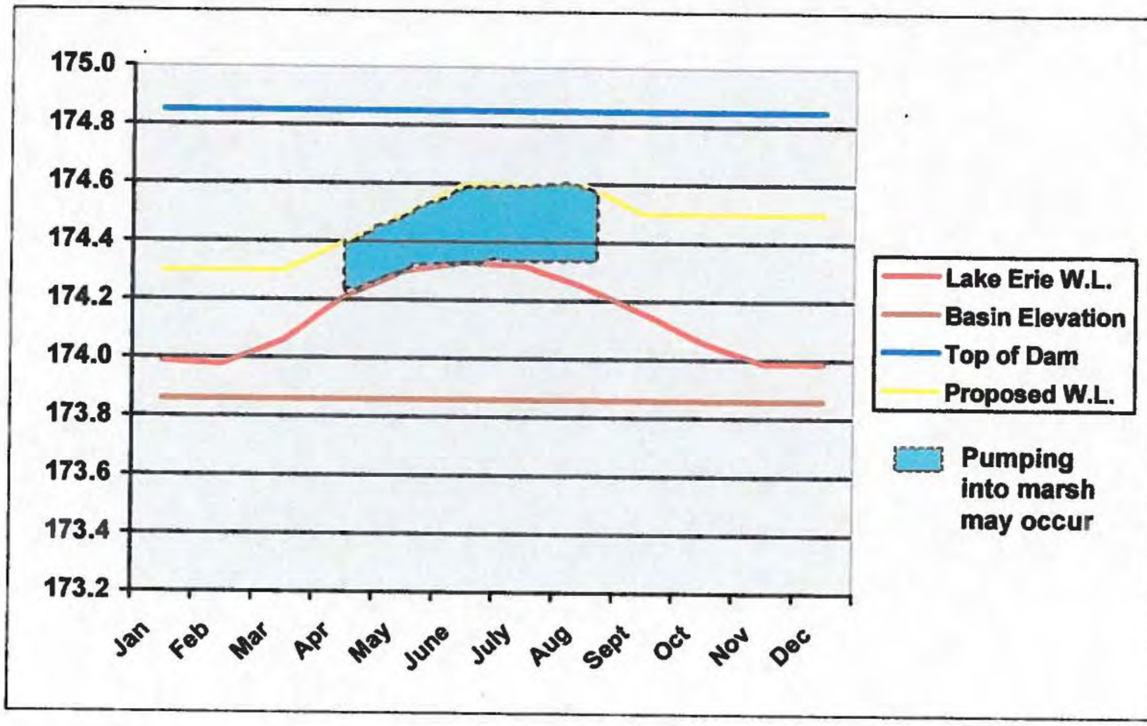
Graph 1. Expected time period of pumping during the hemi-marsh phase.



Graph 2. Expected time period of pumping during the open water phase.



Graph 3. Expected time period of pumping during the overgrown marsh phase.



APPENDIX 1

Summary of April 20, 2006 Consultation Meeting
Between
Creekside Hunting and Fishing Club / Ducks Unlimited Canada
and
the Ministry of the Environment, the Ministry of Natural Resources, Essex Region Conservation Authority and the Department of Fisheries and Oceans

As per Condition 3.7 of PTTW # 0081-6JNPJ5 (Reference Number 8700-6E7N8X), a consultation meeting was held on April 20, 2006 on site with representatives from the Ministry of the Environment, the Ministry of Natural Resources, Essex Region Conservation Authority and the Department of Fisheries and Oceans. Representatives from the Canadian Wildlife Service were also invited but were unable to attend due to spring waterfowl survey commitments. The purpose of the meeting was to present and discuss a draft framework for the water pumping operations plan being developed by the Permit Holder (Creekside Hunting and Fishing Club) for the purpose of sustaining and managing water levels in Big Creek Marsh.

Attendees included;
Scott Muir (Ducks Unlimited Canada), Ed Faucher (Creekside Hunting and Fishing Club), Dan Lebedyk (Essex Region Conservation Authority), Tim Byrne (Essex Region Conservation Authority), Holly Simpson (Ministry of Natural Resources - Chatham), Rick Visser (Ministry of Natural Resources - Chatham), Harald Schraeder (Ministry of the Environment - London), Scott Abernethy (Ministry of the Environment - London), Archie Parastatidis (Ministry of the Environment - Windsor), Joe De Laronde (Department of Fisheries and Oceans - Sarnia), John Sullivan (Canadian Wildlife Service – retired).

The meeting was chaired by Scott Muir (Ducks Unlimited Canada) on behalf of the Permit Holder and commenced with a presentation to the group that included;

- A review of Permit to Take Water 0081-6JNPJ5
- An overview of Big Creek Marsh
- A review of wetland successional ecology
- A historical review of Big Creek Marsh emergent vegetation changes (1947 – 2005) relative to water level changes
- A review of staging waterfowl habitat requirements
- A review of waterfowl use trends of Big Creek Marsh (1972 – 2005)
- A review of Big Creek Marsh hydrology, Lake Erie hydrology, dam and pumping infrastructure hydraulics
- A review of the framework and rationale being proposed for the water pumping operations plan
- A review of the pre and post findings from a study conducted by Environment Canada on a similar managed coastal impoundment with pumping infrastructure that supports the proposed plan framework (Oshawa Second Marsh)

The group agreed that a water pumping operations plan had to be able to effectively address the various habitat limitations associated with different wetland successional stages and supported a proposed three-plan approach that would be directed by various biological indicators, principally the percentage of emergent vegetative cover and open water, plant species and plant distribution.

The group visited the dam site and viewed the infrastructure works in order to better understand their operation and the influence of Lake Erie water levels on the system.

The format of the plan was briefly discussed with Ministry of the Environment representatives Hal Schraeder and Scott Abernathy, in order to ensure that it would be acceptable to them as stipulated in the PTTW.

The meeting concluded and it was agreed that a draft of the plan would be completed and submitted to all attendees of the meeting for review and comment.

APPENDIX 2

Summary of July 19, 2006 Consultation Meeting
Between
Creekside Hunting and Fishing Club / Ducks Unlimited Canada
and
Amherstburg Committee on the Environment
and
Big Creek Association

As per Condition 3.7 of PTTW # 0081-6JNPJ5 (Reference Number 8700-6E7N8X), a consultation meeting was held on July 19, 2006 at the Malden Town Hall with representatives from the Amherstburg Committee on the Environment and the Big Creek Association. The purpose of the meeting was to present a draft water pumping plan for Big Creek Marsh being proposed by the Permit Holder and to engage the Amherstburg Committee on the Environment and the Big Creek Association. Minutes of the meeting were recorded by Deirdre Merritt, reporter for E. Beryl MacMillan, Official Examiner.

Notable attendees included;
Scott Muir (Ducks Unlimited Canada), Ed Faucher (Creekside Hunting and Fishing Club), Dr. John Spellman (Amherstburg Committee on the Environment and Big Creek Association), Dan Lebedyk (Essex Region Conservation Authority), Tim Byrne (Essex Region Conservation Authority), Holly Simpson (Ministry of the Natural Resources), Harald Schraeder (Ministry of the Environment), Scott Abernethy (Ministry of the Environment), Phil Roberts (local birder), Frank Pizzuto (CAO – Town of Amherstburg) and Wayne Hurst (Mayor - Town of Amherstburg).

The meeting was chaired by Dr. John Spellman and several presentations were made by individuals including the Permit Holder. The PowerPoint presentation included

Scott Muir, on behalf of the Permit Holder presented a proposed water pumping operations plan for Big Creek Marsh that had been developed based on feedback received from the April 20th, 2006 consultation meeting with regulatory agency personnel and the first draft plan that had been formally submitted for their further review and comment on June 12th, 2006. The presentation included;

- A review of Permit to Take Water 0081-6JNPJ5 and Condition 3.7
- An overview of Big Creek Marsh and associated wildlife values
- A review of the dam and pumping infrastructure
- A review of wetland successional ecology
- A review of the pre and post findings from a study conducted by Environment Canada on a similar managed coastal impoundment with pumping infrastructure that supports the proposed management plan and the wildlife benefits that can result from sound management (Oshawa Second Marsh)
- A historical review of Big Creek Marsh emergent vegetation changes (1947 – 2005) relative to water level changes
- A review of waterfowl use trends of Big Creek Marsh (1972 – 2005) relative to drastic changes in the wetland composition
- A review of Big Creek Marsh hydrology, Lake Erie hydrology, dam and pumping infrastructure hydraulics
- A review of the three-plan framework and rationale being proposed for the water pumping operations plan
- A review of each management plan based on the different stages of the typical wet-dry cycle of wetlands complete with rationale, monitoring protocol and expected water taking by pumping
    1. Hemi Marsh (30% < emergent cover < 70%)
    2. Open Water Marsh (≤ 30% emergent cover)
    3. Overgrown Marsh (≥ 70% emergent cover)

<u>Summary of the meeting</u>

- the audience generally lacked an understanding of the Permit to Take Water (PTTW) program, the limits of its regulatory powers and felt disenfranchised with the process
- attendees affirmed that Big Creek Marsh is an important feature to the community
- there was both support for and against proactive management of Big Creek Marsh
- attendees expressed a diversity of personal values derived from the marsh
- several attendees understood the association between habitat conditions and wildlife response
- attendees who possessed a practical working knowledge of marsh management generally accepted and supported the concepts presented in the plan
- lack of realization by many attendees that active management cannot benefit all species at a given point in time
- many attendees focused on the perceived short term negatives of a drawdown and not on the long term ecological benefits
- much of the discussion focused on issues that were not related to the proposed pumping plan or the PTTW
- there was limited feedback during the meeting pertaining to the proposed plan and no written feedback was subsequently received by the Permit Holder from any of the attendees

Invasive *Phragmites* – Best Management Practices

2011

ontario.ca/invasivespecies

Ontario

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Front cover photo courtesy of Ontario Federation of Anglers and Hunters.

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Photo courtesy of Dave Featherstone.

Photo courtesy of Janice Gilbert, MNR.

Introduction

The Best Management Practices (BMPs) outlined in this document are designed to provide guidance for controlling the invasive plant *Phragmites australis* subsp. *australis* (common reed) within sensitive habitats (i.e., wetlands, dune ecosystems). These BMPs are also relevant for invasive *Phragmites* control in other areas, including transportation and utility corridors and privately owned properties. Controlling invasive *Phragmites* in these sites is strongly encouraged since they represent potential vectors that can spread *Phragmites*, creating new stands and causing re-introductions of the plant across the province. These guidelines were developed to assist with natural resource management and to compliment initiatives outlined in the Ontario Ministry of Natural Resource's policy and directives pertaining to the preservation of biodiversity, protection of Species at Risk (SAR), and control of invasive species. The BMPs are based on the most effective and environmentally safe *Phragmites* control practices known from research findings, field trials, and experience. Further, they are based upon the most recent information available to date and as new research findings emerge, are subject to change. They adhere to Municipal, Provincial and Federal legislation with respect to herbicide usage, habitat disturbance, and SAR protection. The BMPs are intended to promote a consistent approach to the management of this invasive plant throughout Ontario to support a more effective and efficient control network.

Phragmites australis subsp. *australis* (Common reed) is an invasive perennial grass that is causing severe damage to coastal wetlands and beaches in North America. Identified in 2005 as the nation's "worst" invasive plant species by researchers at Agriculture and Agri-food Canada, invasive *Phragmites* was transported from Eurasia and introduced to North America through a variety of different means, and has been causing noticeable detriment to Canadian coastal and wetland areas for several decades. While it is surmised that *Phragmites* was first introduced along the eastern seaboard, invasive *Phragmites* plants have been identified and located farther west and north of the original point of introduction. Invasive *Phragmites* is currently sold through the horticultural trade as an ornamental plant, and can be spread through various methods, including wind or water.

Invasive *Phragmites* is a non-native plant that creates monoculture stands, which, in most cases, leads to a decrease in biodiversity and a destruction of habitat for other species, including SAR. In Ontario, invasive *Phragmites* has been identified across the southern part of the province, with scattered occurrences as far north as Georgian Bay and Lake Superior. The Ontario Ministry of Natural Resources, along with the support of several partners, is working towards controlling and managing invasive *Phragmites australis*.

Figure 1: A native *Phragmites* stand (left) and an invasive *Phragmites* stand (right). Note the varied vegetation and lower density of native *Phragmites* stalks on the left and the taller, higher density invasive *Phragmites* stalks on the right.

Native stand photo courtesy of Erin Sanders, MNR. Invasive stand photo courtesy of Janice Gilbert, MNR.

The name *Phragmites* is derived from the Greek term *phragma*, meaning fence, hedge, or screen. Invasive *Phragmites* is a subspecies known as *Phragmites australis* subsp. *australis*, and is closely related to the native subspecies *americanus*. Much of the biomass of invasive *Phragmites* is found underground, in an intricate system of roots and rhizomes. Invasive *Phragmites* is an aggressive plant that easily out-competes native species for water and nutrients. Invasive *Phragmites* thrives in disturbed habitats, and is often among the first species to colonize a new area. Invasive *Phragmites*' ability to grow and spread rapidly allows the plant to invade new areas and grow into large monoculture stands in a short amount of time. Invasive *Phragmites* is also an allelopathic plant that actively secretes toxins from its roots into the soil which impede the growth of and even kill off neighbouring plant species. While invasive *Phragmites* prefers areas of standing water, the roots can grow to extreme lengths, allowing the plant to survive in areas with lower water levels by reaching groundwater that is deep below-ground. Invasive *Phragmites* is sensitive to high levels of salinity, low oxygen conditions, and drought, all of which can limit the viability of seeds or rhizome fragments.

Life Cycle of Invasive *Phragmites*

It is important to note that these are general timelines which may vary among sites. Determining the best time period for implementation of a management plan will be site-dependent.

- Dormant: November–March
- Germination: April–May
- Primary vegetative growth: June–July
- Flowering: August–September
- Translocation of nutrients: September–October

Reproduction

Invasive *Phragmites* can reproduce through the dispersal of seeds or roots via rhizomes, or stolon fragments. Dispersal can occur via natural modes of transportation such as water, air, or animal movement, as well as through human actions and equipment including the horticultural trade, boats, trailers, or ATVs. Invasive *Phragmites* rhizomes can grow horizontally several metres per year, while the vertical growth rate is up to 4 cm per day; the plants can produce thousands of seeds annually. While the primary method of reproduction is vegetative as stands spread through the extensions of rhizomes, invasive *Phragmites* seeds are viable, and can lead to the establishment of new populations.

Invasive vs. Native *Phragmites*

The invasive subspecies (*australis*) of *Phragmites* is similar to a native species (subspecies *americanus*), and it is imperative that a stand be identified as either invasive or native *Phragmites* before implementing a management plan. Additionally, when large-scale control is indicated, any stands of native *Phragmites* should be protected from the control measures. Unlike the invasive strain, native *Phragmites* does not require control since it rarely develops into monoculture stands, does not alter habitat, has limited impact on biodiversity, and does not deter wildlife.

While there are several morphological differences that can be considered, it can be difficult to discriminate between the species, and genetic analysis may be necessary in order to accurately determine whether a stand is comprised of invasive or native *Phragmites*. Some identifying characteristics include (but are not exclusive to):

- Stand height
- Stand density
- Stem colour
- Leaf colour
- Seedhead density

Figure 2: A native *Phragmites* stem (left) and an invasive *Phragmites* stem (right). Note the reddish brown native stem on the left, and the tan/beige invasive stem on the right.

Native stand photo courtesy of Erin Sanders, MNR. Invasive stand photo courtesy of Janice Gilbert, MNR.

	Native *Phragmites*	Invasive *Phragmites*
Stand height	No taller than 2 metres	Up to 5 metres (15 feet)
Stand density	Sparse, interspersed with native vegetation	Dense monoculture, up to 100% invasive *Phragmites*
Stem colour	Reddish-brown	Beige, tan
Stem texture	Smooth and shiny	Rough and dull
Stem flexibility	High flexibility	Rigid
Leaf colour	Yellow-green	Blue-green
Leaf sheaths	Fall off in fall, easily removed	Remain attached, difficult to remove
Lower glume	3.7–7 mm	2.6–4.2 mm
Flower timing	Early (July–August)	Intermediate (August-September)
Seedhead density	Sparse, small	Dense, large

Invasive *Phragmites* stands can grow up to 5 metres tall (15 feet), and grow much more densely than native *Phragmites*, with up to 200 stems per square metre. These near-monoculture stands create areas that are low in biodiversity, and are composed of a high percentage of invasive *Phragmites*, up to 100%. Native *Phragmites* does not grow as tall as the invasive subspecies, and does not out-compete other native species, allowing for a higher level of diversity of native vegetation within a stand (Figure 1). Invasive *Phragmites* stems are generally tan or beige in colour with blue-green leaves and large, dense seedheads, in contrast to the reddish-brown stems, yellow-green leaves, and smaller, sparser seedheads of native *Phragmites* (Figure 2, 3, and 4). While it is suspected that cross-breeding may occur between invasive and native *Phragmites* plants, hybridization has only been produced in laboratory settings, and no hybrids have been confirmed in the field. Where the plant is found in certain environmental conditions such as those that occur along sandy coastal shorelines and deep water systems, the morphological differences described above are not definitive. In these cases, it is recommended that a *Phragmites* expert be consulted or DNA analysis be performed.

How to Prevent the Spread of Invasive *Phragmites*

- **Do not purposely plant it**: Invasive *Phragmites* is available for purchase at garden and horticultural centres, but gardeners should consider using only native plants in their water gardens. By choosing to not plant invasive *Phragmites* in a garden, the risk of spread is limited.
- **Avoid transportation via equipment**: When leaving an area containing *Phragmites*, be sure to brush off clothing and clean off equipment on-site to avoid the transfer of seeds to new sites.
- **Do not attempt to compost invasive *Phragmites***: Seeds and rhizomes can survive and grow in a compost heap, creating a new stand or dispersing to other areas. In order to dispose of invasive *Phragmites*, plants should be dried and burned or disposed of in the garbage or at a landfill.

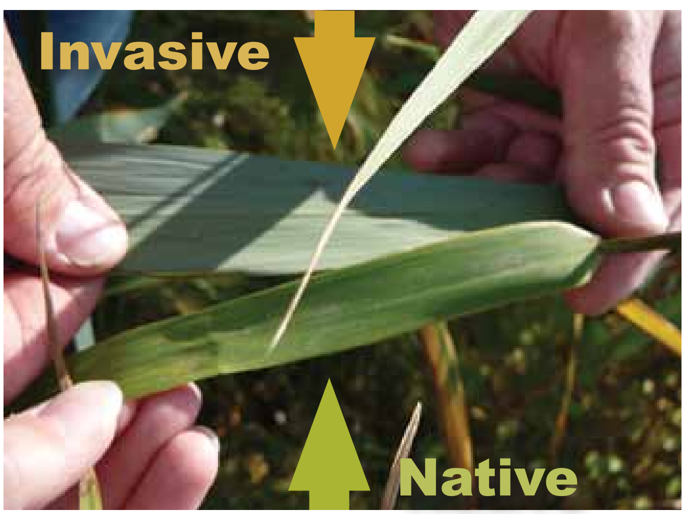

Figure 3: A native *Phragmites* leaf (bottom) and an invasive *Phragmites* leaf (top). Note the yellow-green native *Phragmites* leaf, and blue-green invasive *Phragmites* leaf above.

Photo courtesy of Erin Sanders, MNR.

Figure 4: A native *Phragmites* seedhead (top) and an invasive *Phragmites* seedhead (bottom). Note that the native *Phragmites* seedhead is smaller and sparser compared to that of the invasive *Phragmites*.

Photo courtesy of Erin Sanders, MNR.

Effects of Invasive *Phragmites*

- **Loss of biodiversity and species richness**: Invasive *Phragmites* causes a decrease in biodiversity by creating monoculture stands. *Phragmites* stands crowd out native vegetation and hinder native wildlife from using the area, resulting in a decrease in both plant and animal biodiversity.

- **Loss of habitat**: Monoculture *Phragmites* stands result in a decrease in available natural habitat and food supply for various wildlife species, which may include Species at Risk. Invasive *Phragmites* stalks are rigid and tough, and do not allow for wildlife to easily navigate through or nest in a stand.

- **Changes in hydrology**: Invasive *Phragmites* displays very high metabolic rates, which can lead to changes in the water cycles of a system. Monoculture stands of invasive *Phragmites* have the ability to lower water levels, as water is transpired at a faster rate than it would be in an area of native vegetation.

- **Changes in nutrient cycling**: Invasive *Phragmites* stalks are made of a very inflexible structural material which breaks down very slowly. This slows the release of nutrients and leaves a high proportion of recalcitrant biomass (carbon) in the standing dead stalks.

- **Increased fire hazards**: A stand of invasive *Phragmites* is composed of a high percentage of dead stalks, with a lower percentage of live growth. Dead stalks are dry and combustible, increasing the risk of fires.

- **Economic and social impacts**: Invasive species such as *Phragmites* can have many negative effects on economic and social issues. Effects on agriculture and crops can lead to economic losses, while monoculture stands can affect property values, and raise aesthetic concerns.

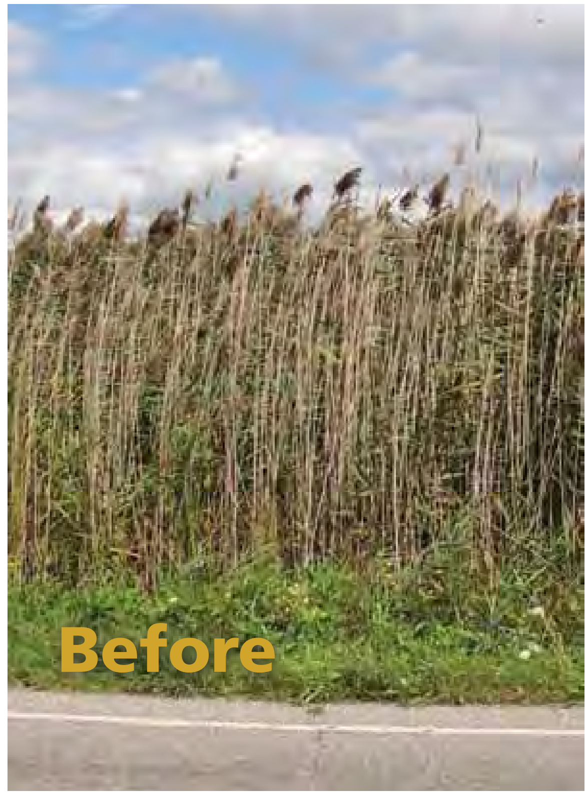

Figure 5: A study site at MacLean's Marsh, using 5% glyphosate. Before: Pre-treatment, 2007. After: Post-treatment, 2008. Note: There was no standing water in this area at the time of treatment.

Photos courtesy of Janice Gilbert, MNR.

Control Measures

Controlling invasive *Phragmites* before it becomes well-established will reduce the environmental impacts, time, and costs. The effectiveness of early detection and reporting is greatly increased through public education. Proper identification of the plant as the invasive *Phragmites* species is critical. Once the existence of the plant in an area has been confirmed, a control plan should be developed and implemented in a timely fashion following best management practices (BMPs).

Since these BMPs are designed to assist with *Phragmites* control in natural habitats, consideration must be taken with regard to site specific conditions such as native plant diversity, wildlife usage, and water table fluctuations. It is strongly recommended that a detailed inventory of each site be completed prior to initiating control efforts. This will help ensure that the proper control methods and timing are selected, thus minimizing negative impacts to the system. Recreational usage as well as human and domestic animal presence around control sites must also be taken into consideration especially when herbicides are being used.

Due to the extensive underground rhizome system created by invasive *Phragmites*, the use of a single control measure is not always effective, as disturbance to an area may actually increase the density and spread of an invasive *Phragmites* stand. The Ontario Ministry of Natural Resources recognizes the need for an integrated pest management (IPM) plan, which comprises two or more methods, and these long-term plans should be created in a site-specific manner. Furthermore, long-term management plans should follow up initial treatments with frequent monitoring and re-assessment, as well as subsequent treatment if necessary, using whichever measures are likely to be most effective in that area. In order to determine which combination of control measures will be most effective in a given area or situation, there is a consistent need for case-by-case assessments. It is important to note that once an invasive

Photo courtesy of Francine MacDonald, OFAH.

Photo courtesy of Janice Gilbert, MNR.

Phragmites stand has been established, it is very difficult to completely eradicate the stand, and that IPM plans are meant to control and mitigate the invasive population as effectively as possible.

Management options for the control of invasive *Phragmites* include mechanical excavation, flooding, herbicide application, and prescribed burning. However, none of these methods are fully effective when used alone. When used improperly, these control measures may actually worsen the problem. As indicated by current research and field experience, the most effective management plan for most situations includes a combination of herbicide application, cutting/rolling, and prescribed burning, following very strict timelines. Site conditions and access will dictate which options are best-suited for controlling invasive *Phragmites*. Due to herbicide label restrictions that prohibit the use of the herbicide in or over water, sites that are flooded with water for the entire growing season cannot be controlled using the available herbicides. This limits control options, and unfortunately, for some sites, none of the currently available options may be feasible or effective. When performing these control measures, it is important to limit wildlife disturbance and damage to habitat, and determine the best treatment timing.

It is recommended that all sites to be controlled for invasive *Phragmites* first undergo an assessment of the flora present and wildlife usage. The results of such an assessment will help to direct the best course of action for control with the least impact to the habitat that is to be protected, as well as any plants that are to be preserved. The presence of SAR flora or fauna at the site should become the greatest consideration in control planning. There are a number of mitigation efforts that can be put in place to reduce potential harm to plant SAR, including timing. In some cases, the leaves of mature SAR plants may be stripped to reduce exposure to herbicide mist, or the plants may be covered during spraying. Coastal habitats such as wetlands and dune systems provide invaluable habitat for a high number of SAR. Knowledge of the habitat usage requirements of the particular species observed at the site for each life cycle component will provide the information required to design measures that significantly reduce harm to these animals.

The success of the initial control project is dependent upon a number of factors including stand density, accessibility, and the range and effectiveness of control options employed. Complete eradication of invasive *Phragmites*, particularly in well-established stands, is rarely achieved after one treatment. Depending upon the site, annual visits and touch up control work will likely be required for a few years after initial treatment takes place. The need to inspect the site for new invasions and subsequent treatments should significantly decline over time. It is strongly recommended that post-treatment assessments be conducted to track control efficacy and guide future management. After treatment, the residual seedbank of native plants in an invasive *Phragmites* stand is usually able to repopulate the area, and regeneration of native plants should be seen in the subsequent growing seasons. Some sites may require seeding or planting of desired vegetation post-treatment, particularly if plant diversity before the establishment if invasive *Phragmites* was depressed due to the presence of other invasive plants or other factors.

It is critical to ensure that all necessary permits are obtained and regulations followed with regards to strategies such as herbicide application and prescribed burning. When controlling or removing invasive *Phragmites*, care should be taken to minimize disturbance, and cause as little damage as possible to native vegetation and wildlife.

Herbicide Application

In order to eradicate an invasive *Phragmites* stand, it may be necessary to apply herbicides. While using herbicides is not always an ideal solution, it is important to bear in mind that, in some situations, the detrimental effects of allowing invasive *Phragmites* to flourish can far outweigh the negative effects of pesticide use.

There are many regulations surrounding the use of chemicals for the control of invasive species, and specific precautions must be taken before applying herbicides, as well as necessary permits obtained from the appropriate governing bodies. In Ontario, herbicide storage, use, transport, and sale is regulated under the *Pesticides Act* and Regulation 63/09, which can be viewed at the following link: www.e-laws.gov.on.ca/html/source/regs/english/2009/elaws_src_regs_r09063_e.htm#BK37

While there are regulations regarding the use of herbicides for forestry or agricultural operations, this BMP document focuses on control measures for natural resource management. Section 33 under Regulation 63/09 provides an exception for Class 9 pesticides (i.e., pesticides that are prohibited for cosmetic use purposes) to be used for natural resource management purposes. Class 9 pesticides can be used by the following persons, if they hold the appropriate exterminator license:

- an employee of MNR;
- an employee of a Conservation Authority;
- an employee of a body having a written agreement with MNR to manage natural resource features; or
- a licensed exterminator providing a service to MNR, a Conservation Authority, or a body responsible for managing a natural resource management project under a written agreement with MNR.

If the extermination will be done by a body not mentioned above, including private landowners, then in order to apply a banned herbicides for the control of invasive species, a written Letter of Opinion is required from the Branch or Regional Director of the Ministry of Natural Resources. Depending on the site, other agency approvals may also be necessary. Furthermore, proper public notification signage as prescribed in Regulation 63/09 is required to be posted at all treated areas. When using an herbicide, it is a legal requirement to follow the directions found on the label, while adhering to all provincial and federal regulations.

The expenses associated with herbicide application are not subsidized by MNR, and can vary. Expenses may include the costs of the chemicals, equipment, and hiring trained personnel.

Herbicide type:

When selecting an herbicide, there are many factors that should be considered. It would be best to choose an herbicide that is specifically designed for use on grass species, as opposed to broad-spectrum herbicides which kill all plants. Herbicides with high animal LD50 values indicate low acute toxicity levels for wildlife. Herbicides that are broken down microbially into harmless compounds have a short half-life, and are preferred. Herbicides used for *Phragmites* control should be able to translocate from the application site (usually the leaves or stems) down to the roots, effectively killing the entire plant.

In North America, there are two herbicide active ingredients that have been shown to be effective in *Phragmites* control: glyphosate and imazapyr. Both herbicides are formulated into products under a range of common or brand names, and have shown similar effects in killing invasive *Phragmites*. Imazapyr is a more effective herbicide, but is also more expensive than glyphosate. Research in the United States has indicated that using a management plan that combines the two herbicides can decrease costs, while maintaining high levels of efficacy. Ideally, alternating herbicide active ingredients also decreases the chances of *Phragmites* developing resistance to one or the other herbicides.

Information and regulations regarding the use of herbicides, including precautions, storage, disposal, solution concentrations, and buffer zones can be found on the following website: http://pr-rp.pmra-arla.gc.ca.

Methods of application:

Herbicides can be applied to a stand of invasive *Phragmites* through a variety of methods, including spraying and wicking. Choosing an appropriate method will depend on the characteristics of the site, as well as the logistics of the overall management plan for the area. Because the products are broad-spectrum herbicides, is it important to target monocultures or stands that are composed of a large fraction of invasive *Phragmites*, and limit application to the upper canopy, avoiding native vegetation growing in the understory. However, even in lower-density stands, the use of herbicides can be effective, since less chemical is needed to control a stand, and native species have been shown to respond well once the invasive *Phragmites* is removed.

Spraying herbicides is effective for dense monoculture stands of invasive *Phragmites*. Spraying herbicides directly onto the leaves of an invasive *Phragmites* stand using high pressure is a common method of herbicide application. Spraying can be performed with a small backpack sprayer or with a larger boom sprayer attached to an all-terrain vehicle (ATV) or similar vehicle. Backpack spraying is effective in areas where a boom sprayer cannot easily gain access, and is also more useful in *Phragmites* stands which are intermixed with native vegetation or for follow-up to a previously treated stand, as the backpack method allows for targeted spraying. Larger sprayers can effectively target dense stands that are larger in area. When spraying, it is important to work within weather and wind conditions that limit any non-target drift to plants or wildlife present in the area.

Wicking or daubing is effective for small stands, and allows for the application of an herbicide to specific plants, while avoiding native vegetation. Hand-wicking involves direct contact with each individual *Phragmites* stalk using an absorbent glove which has been soaked in the herbicide, while daubing employs the use of an applicator to directly apply the herbicide to the plants. These methods are also useful in situations where wind and weather conditions do not allow for spraying. However, hand-wicking is labour-intensive, and may be difficult to perform on tall stands or stands where not all of the plants are easily accessible.

Photo courtesy of Janice Gilbert, MNR.

It is important to note that for all applications methods, the herbicide must be translocated from the application site to the roots. If the stems are broken during the application, the herbicide will not be able to move to the roots, and will thus provide unsatisfactory results.

Concentration:

The concentration of the herbicide in a spray or wicking treatment will affect the ability of the pesticide to enter and control the plant. When using an herbicide, the label directions must be followed as required by federal legislation. In addition, this is also a requirement under the *Pesticides Act* and Regulation 63/09. Information regarding the appropriate mixing instructions of the pesticide can be found product label.

Timing:

The optimum window for *Phragmites* control using an herbicide occurs between early spring, when plants begin to emerge, until late fall, when the first heavy frost causes significant die off. Within this window, there are a number of considerations to be made with regard to herbicide use program timing. If herbicide application is to be used on *Phragmites* stands that are flooded with water, then control using an herbicide must be postponed until all surface water is gone. For Great Lakes coastal habitats, water levels are generally highest in the spring, and depending on the weather, levels start to decline mid summer and continue declining throughout the fall. The extent and timing of the de-watered areas will be dependent upon site-specific topography and other conditions.

Habitat usage is another important consideration. Wildlife is rarely observed in the centre of large *Phragmites* stands, but is commonly observed in smaller, narrower stands, or at the edge of stands. Depending upon the type and density of wildlife usage, controlling *Phragmites* may be best left for late summer or fall when young animals are mobile and wildlife usage is generally far less.

By postponing spray events until late summer/early fall, most native plants will have become dormant or died for the season and/or their seeds will have matured. At this time, invasive *Phragmites* will still be translocating nutrients into the root system, and is capable transporting the herbicide into the roots. The invasive *Phragmites* remains active much later into the fall and is one of the last herbaceous plant species observed to mature and for stalks to die off naturally.

Photo courtesy of Janice Gilbert, MNR.

Mowing

Mowing of an invasive *Phragmites* stand can be performed using tools or by hand-cutting stems and seedheads. Mowing does not affect the root system of an invasive *Phragmites* stand, and if used as a standalone control method, cutting may stimulate the growth and increase the density of a stand. When considering mowing as a management method, it is important to be aware of soil moisture and other conditions that allow the soil to support heavy equipment, as these can impede the ease and efficacy of mowing, and lead to safety concerns. Mowing should be conducted in late July/early August, when most of the carbohydrate reserves are in the upper portion of the plant (i.e., during seed production or flowering). Mowing is considered to be a relatively low-cost method, and one that can be easily performed with minimal training. All clothing, boots, and equipment should be cleaned on-site to avoid the transportation and dispersal of invasive *Phragmites*. There are two mowing methods to consider:

1) **As part of an IPM plan:** Mowing or cutting an invasive *Phragmites* stand is an important component of an IPM plan. Mowing compacts the dead biomass, and allows for a more effective and efficient prescribed burn to follow. It also removes dead biomass, and allows for spot treatment of new invasive *Phragmites* growth, and for new native plants to grow. Herbicide treatment prior to mowing can help in reducing the moisture content of stalks and leaves. When combining mowing with herbicide application, mowing should occur at least two weeks after herbicide treatment, to allow for translocation of the herbicide to the roots.

2) **As a standalone control method:** In some cases, it is necessary to mow or cut an invasive *Phragmites* stand without the treatment with an herbicide. This is not an advisable method, as it has shown to be ineffective in controlling invasive *Phragmites*. However, if cutting is necessary, herbicides can still be applied to a mowed stand at the appropriate time of year. In low-nutrient sites it may be possible to stress the plants enough to

dampen re-growth under a repeated cutting regime. If the seedheads of a plant are removed before nutrients can be provided to the root system, it may be possible to effectively exhaust the root reserves, causing the plant to die. Cutting must occur several times throughout the entire growing season over a course of several consecutive years for any improvements to occur.

When considering mowing as a standalone control method, it should be limited to areas that contain predominantly invasive *Phragmites*, to avoid broad-scale mowing of other native vegetation. Invasive *Phragmites* stalks should be cut to a height of no taller than 10 centimetres. Mowing may occur more than once per season, and should be repeated the following seasons in order to control regrowth. Caution should be taken to avoid soil disturbance and the distribution of seeds or rhizomes, which may lead to increased growth and spread of the stand. Cut debris and leftover dead biomass should be removed to allow native vegetation to grow, and disposed of in the proper manner.

Compressing or Rolling

Compressing or rolling dead stalks using a roller acts in a similar manner to mowing or cutting. Similarly, compressing is not effective as a standalone control method for invasive *Phragmites*, and is most effective when used as part of an integrated management plan. Compressing compacts the dead biomass, and allows for a more effective and efficient prescribed burn to follow. It also allows for easier visibility and spot treatment of new invasive *Phragmites* growth. Compression or rolling may occur at any time after the plant is dead, once the herbicides have had an opportunity to translocate throughout the plants, killing the rhizomes and root system, and after any wildlife using the stand as habitat have vacated the area.

Photo courtesy of Ric McArthur.

Prescribed Burning

Prescribed burning is the planned and deliberate use of fire by authorized personnel, and it should be used as part of an integrated management plan, following herbicide application. The role of fire is to remove biomass that prevents establishment of native vegetation and to provide a source of material for vegetative reproduction. The maximum benefit from fire is obtained when it is done a minimum of two weeks after herbicide treatment, following mowing or rolling of the dead stalks. Prescribed burning without the prior use of herbicides is not an effective control method, and may encourage rhizome growth, leading to the spread or increased growth of a stand. It is strongly recommended that burning does not occur on standing dead *Phragmites* stands since this creates an extreme challenge for fire containment and a very high risk to personal safety. Prescribed burning should be used as a way to remove excess above-ground biomass and seeds, promoting native plant growth, and allowing for easier spot treatments of residual plants the following season. In an area that has already been treated with herbicides, prescribed burning should be conducted in the fall, after the herbicides have had an opportunity to translocate throughout the plants, killing the rhizomes and root system. Prescribed burning can also be used in the spring season for sites that are not flooded with water. Burning of the dead material has been observed to speed native plant species establishment. The removal of the "straws" through burning assists to drown surviving plants in areas that do flood lessening *Phragmites* re-emergence.

Prescribed burning should always be performed by authorized personnel, following federal and provincial guidelines and regulations. Prescribed burning is cost-effective and ecologically sound, and if done on sites with other fire-tolerant species, may benefit the re-growth of native species.

Hand-pulling or Mechanical Excavation

Hand-pulling or mechanical excavation is not an advisable method, as it is very labour-intensive, and is ineffective in controlling invasive *Phragmites*. Mechanical removal is only advisable when it can be assured that no plant material remains on-site. When hand-pulling is the only option, it is most effective on plants that are less than two years old and found in dry, sandy soils. When removing invasive *Phragmites* plants manually, ensure that all portions of the rhizomes are removed from the ground, and that all parts of the plant are disposed of in the appropriate manner, as described in the section of this document titled "Disposal."

Photo courtesy of Darren Jacobs.

Flooding

The flooding of invasive *Phragmites* stands has varied results, and is a difficult method to undertake. In order to effectively flood an invasive *Phragmites* stand, the stand must be in an area in which water levels can be easily controlled. Before flooding, a stand should be cut to as low a height as possible. Flooding should occur in late summer, in order to maintain and promote native vegetation, while avoiding the reestablishment of invasive *Phragmites*. Water levels must be maintained at a minimum of 1.5 metres taller than the entire stand, and levels must be kept at this height for a period lasting at least 6 weeks, over the course of the growing season. In wet sites where this is not feasible, it may be possible to drown newly emerging plants in the spring with shallower water levels. In order for drowning to be effective, all standing dead biomass from previous years must first be removed either by cutting, rolling or burning. Removing all the remaining dead stalks, which normally extend above the water surface, reduces oxygen diffusion to the root system.

Tarping

Tarping or solarization of invasive *Phragmites* stands has shown varied results, and is not a recommended method of *Phragmites* control, as it is non-selective, and will affect all native vegetation as well as damage soil biota populations. Tarping works best in *Phragmites* stands that are found in areas of direct sunlight. Before tarping, the invasive *Phragmites* plants must be cut to less than 10 cm, and dead biomass must be removed or flattened. Black plastic tarp or geotextile sheets are then anchored over the area using stakes or weights; the tarps should cover a large buffer area beyond the perimeter of the *Phragmites* stand. Sunlight will cause high temperatures to develop under the plastic, which will eventually kill the plants. While this method is not labour-intensive, continual and frequent monitoring of the *Phragmites* plants along the perimeter is necessary, as there may be runners that grow out from beneath the tarp. The plastic tarp must stay in place for a minimum of six months, in order to ensure complete suppression of the invasive *Phragmites* stand.

Photo courtesy of Janice Gilbert, MNR.

Biological Controls

Invasive species that are new to an area do not generally have the same predation pressure that they would in their native habitat. An effective way to manage invasive *Phragmites* would be to introduce a biological control. Currently, researchers at Cornell University in New York are investigating several insects that feed on *Phragmites* which occur naturally in North America, but at this time, there are no biological controls available for invasive *Phragmites*.

Disposal

Invasive *Phragmites* is a very vigorous species, and stands can establish from the dispersal of seeds or stolon fragments from the rhizome. Thus, care must be taken when transporting and disposing of trimmings from mowing or cutting of invasive *Phragmites* stands. Invasive *Phragmites* clippings should not be composted; cut plants should be bagged in thick plastic bags, and allowed to dry out or decay in the sun to kill all viable seeds and rhizomes. Dried and dead *Phragmites* plants can be burned or the bags must be disposed of at an appropriate municipal staging or disposal location, and it is advisable to contact local municipalities prior to disposal. All clothing, boots, and equipment should be cleaned on-site to avoid the transportation and dispersal of invasive *Phragmites*.

Best Management Practices for Invasive *Phragmites* Control in Ontario

In *Phragmites* stands where there is standing water present:

- Herbicides CANNOT be applied.
- Cut/mow the stalks as low as possible.
- Tarping/solarization is another option, but may not be as effective in standing water.

In *Phragmites* stands where the water level can be controlled:

- Cut/mow the stalks as low a height as possible.
- Maintain the water level so that it remains a minimum of 1.5 m taller than the entire stand for a period of at least 6 weeks.

In *Phragmites* stands where there is no standing water present:

- Perform wildlife assessments.
- Time herbicide application appropriately.
- If necessary, mow or roll the stand to compact the dead biomass.
- If appropriate, perform a prescribed burn in the area.
- Monitor and perform follow-up treatments as necessary.

Partners and Resources

- Ontario Ministry of Natural Resources
  www.mnr.gov.on.ca
- Ontario Ministry of the Environment
  www.ene.gov.on.ca
- Environment Canada
  www.ec.gc.ca
- Government of Canada Invasive Species
  www.invasivespecies.gc.ca
- Ontario Federation of Anglers and Hunters
  www.invadingspecies.com
- Ontario Invasive Plant Council
  www.stewardshipcentre.on.ca/index.php/oipc_pages
- Ontario Parks
  www.ontarioparks.com
- Turkey Point Provincial Park
  www.ontarioparks.com/english/turk.html
- Wasaga Beach Provincial Park
  www.wasagabeachpark.com
- Rondeau Provincial Park
  www.rondeauprovincialpark.ca
- Parks Canada
  www.pc.gc.ca
- Ontario Stewardship
  www.ontariostewardship.org
- Conservation Ontario
  www.conservation-ontario.on.ca
- Canadian Wildlife Service
  www.cws-scf.ec.gc.ca
- Lake Huron Centre for Coastal Conservation
  http://lakehuron.ca
- Bird Studies Canada/Long Point Waterfowl
  www.bsc-eoc.org
- Ducks Unlimited
  www.ducks.ca
- Michigan Department of Environmental Quality
  www.michigan.gov/deq
- Cornell University
  www.invasiveplants.net/phragmites
- Monsanto (Roundup)
  www.monsanto.ca

Control Method	Pros	Cons	Timing	Notes/Cautions
Herbicide Application	▪ Most effective method ▪ Can be cost-effective	▪ Must be used in conjunction with other methods ▪ Can only be used in dry areas ▪ Non-specific	▪ Spring to late fall (pre-senescence)	
Mowing/Cutting	▪ Low cost	▪ Can be labour-intensive ▪ Not effective when used as a standalone method ▪ Non-specific	▪ If using as part of an IPM: At least 2 weeks after herbicide application ▪ If using alone: when the plant is flowering/producing seeds	
Compression/Rolling	▪ Low cost	▪ Non-specific	▪ If using as part of an IPM: At least 2 weeks after herbicide application ▪ If using alone: when the plant is dead and dried	
Prescribed Burning		▪ Not effective when used as a standalone method ▪ Non-specific	▪ If using as part of an IPM: At least 2 weeks after herbicide application ▪ Should be conducted when conditions are as dry as possible	▪ Should always be performed by authorized personnel, following federal and provincial guidelines and regulations as necessary.
Hand-pulling / Mechanical Excavation	▪ Can easily target specific *Phragmites* plants ▪ More effective on small, isolated stands of plants less than 2 years old ▪ Good for dry, sandy soils	▪ Very labour-intensive ▪ Not effective for large stands		▪ Caution regarding soil disturbance ▪ Must ensure all portions of the rhizomes are removed from the ground
Flooding	▪ Minimal effects on wildlife	▪ Can be used in areas where water levels can be controlled or are naturally prone to floods ▪ Non-specific		
Tarping	▪ Minimal effects on wildlife	▪ Not always effective ▪ Large impact on soil flora ▪ Non-specific		
Biological controls	▪ Target specific plants	▪ Very long timelines ▪ Not yet available		▪ More research needed

Table 1: Summary of Control Methods.