The Ecology of Old Woman Creek, Ohio:
An Estuarine and Watershed Profile

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Second Edition

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Office of Ocean and Coastal Resource Management
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Old Woman Creek was designated as a State Nature Preserve in 1980 and as a National Estuarine Research Reserve in the same year. It serves as a field laboratory where scientists can study this naturally functioning system and where students and the public can learn about estuarine ecology in a natural setting. The Reserve is a cooperative partnership between the Ohio Department of Natural Resources and the National Oceanic and Atmospheric Administration.

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The Ecology of Old Woman Creek, Ohio:
An Estuarine and Watershed Profile—Second Edition

Written By Charles E. Herdendorf, David M. Klarer, and Ricki C. Herdendorf

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Catalogue of the Vertebrate Fauna of Old Woman Creek Estuary, Watershed, and Environs. Old Woman Creek State Nature Preserve and National Estuarine Research Reserve Tech. Report No. 11. Site Profile Contribution No. 2. Ohio Dept. Natural Resources, Div. Natural Areas and Preserves, Columbus, OH. 3 pp. + 3 figs. + 12 app. (74 pp.). 2001.

Catalogue of the Invertebrate Fauna of Old Woman Creek Estuary, Watershed, and Adjacent Waters of Lake Erie. Old Woman Creek State Nature Preserve and National Estuarine Research Reserve Tech. Report No. 12. Site Profile Contribution No. 3. Ohio Dept. Natural Resources, Div. Natural Areas and Preserves, Columbus, OH. 20 pp. + 2 figs. + 4 app. (106 pp.). 2001.

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General Table of Contents

Expanded Contents

Chapter 5. Hydrology (cont'd)

List of Tables

Chapter 6. Biology

Chapter 7. Ecology

Chapter 8. Archaeology

Chapter 9. Land Use

Chapter 10. Conclusions

Chapter 11. Acknowledgments

Chapter 12. Appendixes

Chapter 13. Glossary

Chapter 14. References Cited

List of Figures

Page

Chapter 1. Introduction

Chapter 2. Geology

CHAPTER 3. SOIL SCIENCE

Chapter 3. Soil Science (cont'd)

Chapter 4. Climatology

Chapter 5. Hydrology

Chapter 6. Biology

Chapter 6. Biology (cont'd)

CHAPTER 7. ECOLOGY

Chapter 7. Ecology (cont'd)

Chapter 8. Archaology

Chapter 9. Land Use

CHAPTER 9. LAND USE (cont'd)

CHAPTER 10. CONCLUSIONS

CHAPTER 11. ACKNOWLEDGMENTS

CHAPTER 12. APPENDIXES

CHAPTER 13. GLOSSARY

CHAPTER 14. REFERENCES CITED

Old Woman Creek estuary (artist: Jim Dickens).

Chapter 1. Introduction

Purpose of Site Profile

In the 25 years that Old Woman Creek National Estuarine Research Reserve has been in existence over 200 research and monitoring projects have been completed by the professional staff and visiting researchers. The results of these studies have been reported in numerous scientific publications, technical reports, and student papers (Herdendorf et al. 2000a,2001a). Through a series of courses and workshops held at the Reserve, research results have been transferred to a wide array of users. Building on earlier studies, all of these activities have added materially to our knowledge of this estuary, its watershed, and the adjoining waters of Lake Erie, and to our understanding of the complex ecological interactions that take place in these environments. The purposes of this Site Profile are to provide an overview of what we have learned about Old Woman Creek estuary and its environs in the past two decades, and to present general concepts that can be transferred to other estuarine and coastal wetland environments throughout the Great Lakes region. To achieve these objectives, the Site Profile process is designed to: (1) compile scientific datasets relating to the Reserve, (2) characterize the physical and biotic components of the environment, (3) synthesize the known ecological relationships within the Reserve and its watershed, (4) trace the impact of natural and human disturbances, and (5) explore the need for future research, education, and management initiatives. Old Woman Creek estuary is unique in the National Estuarine Research Reserve program, in that it is the only Great Lakes and freshwater estuary in the system (Figures 1.1 and 1.2).

What is a Freshwater Estuary?

The *Glossary of Geology* (Bates and Jackson 1980, Neuendorf et al. 2005) defines a freshwater estuary as: "(a) An estuary into which river water pours with sufficient volume to exclude salt water" and "(b) In the Great Lakes and other large lakes, the lower reach of a tributary to the lake that has a drowned river mouth, shows a zone of transition from stream water to lake water, and is influenced by changes in lake level as a result of seiches or wind tides. It is commonly separated from the adjacent main body of water by a barrier spit or baymouth bar." Leverett and Taylor (1915), in their classical monograph on the glacial history of the Great Lakes, were among the first scientists to apply the term "estuary" to a Great Lakes situation. In a section titled *Development of the Detroit River Estuary,* they observed that the shores of western Lake Erie are distinctively drowned, presumably by a relatively recent rise in lake level as indicated by "drowned stream courses" and by E. L. Moseley's description (1905) of submerged tree stumps and stream valleys in Sandusky Bay. Ver Steeg and Yunck (1935) were also early investigators who recognized this circumstance, stating "Since the removal of ice from the area of eastern Canada, the land has gradually tilted the Great Lakes to the southwest. The rise of water level in western Lake Erie has produced estuaries at the mouths of the Maumee, Portage, and Sandusky Rivers, the good harbors at Toledo, Port Clinton, and Sandusky." Although the term estuary has been in the scientific literature for 85 years in reference to certain Great Lakes tributary mouths, it has only recently gained wide acceptance as a useful term to describe many Great Lakes coastal wetlands and embayments (Brant and Herdendorf 1972, Herdendorf 1990,2004).

Pritchard (1967) defined an estuary as "a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water from land drainage." The three basic concepts: (1) constriction, (2) continuous water exchange, and (3) mixing of two dissimilar water masses, one from an open body and another from land drainage, can logically be applied to many Great Lakes tributary mouths where submergence has taken place (Herdendorf 1990). Several investigations have demonstrated the encroachment of lake water into the estuaries and the subsequent mixing of lake and river waters, such as the Cuyahoga River (Schroeder and Collier 1966) and the Maumee River (Herdendorf 1970). In Old Woman Creek estuary, Klarer and Millie (1989) found that storm water was ameliorated as it flowed through the estuary, lowering the concentration of nutrients by more than half. Bedford (1989) contrasted transport mechanisms in Lake Erie tributaries to those operating in marine estuaries and concluded that although there is negligible propagation of lunar-solar driven tide waves, there are transport analogies within Lake Erie estuaries associated with meteorologically induced water level fluctuations and chemical gradients.

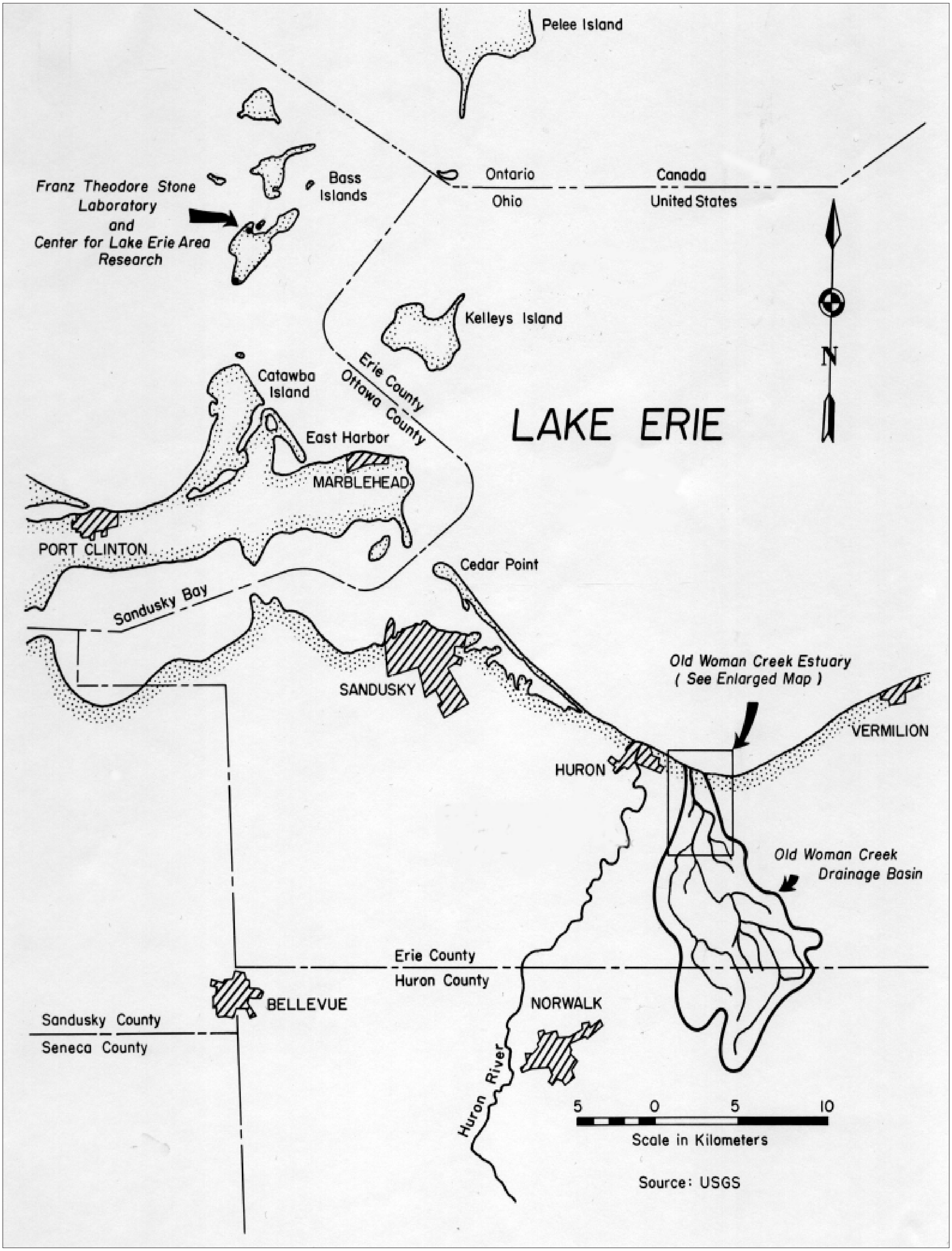


Figure 1.1. Location map of Old Woman Creek estuary and watershed.

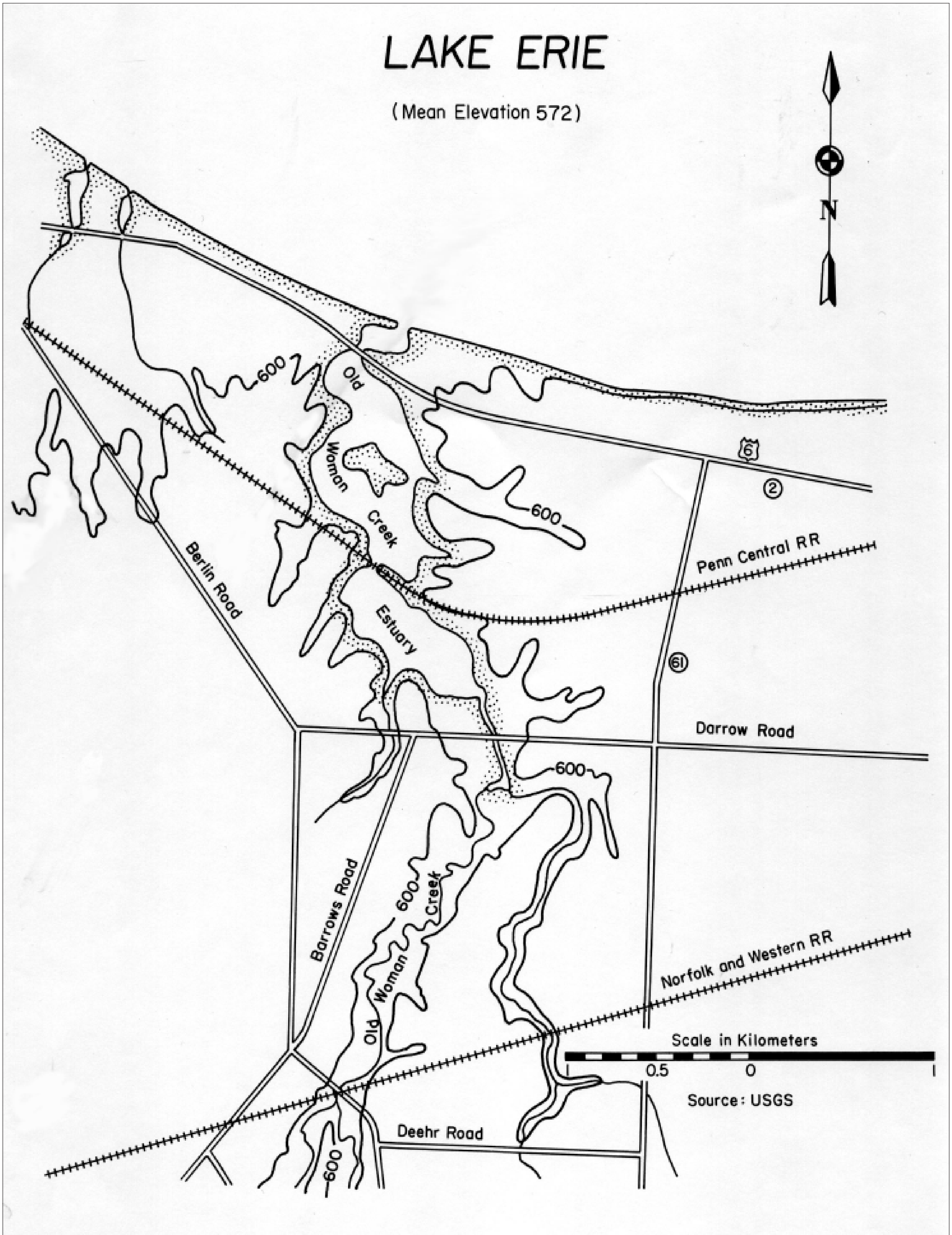


Figure 1.2. Lower reach of Old Woman Creek and its estuary in 1975. Elevations in feet above mean sea level.

FUNCTIONS AND VALUES OF FRESHWATER ESTUARIES

As coastal wetlands of the Great Lakes, freshwater estuaries perform important environmental functions and therefore are of considerable resource value to the region. Great Lakes estuaries support highly productive, diverse biotic communities which interface between the aquatic environments of the open lake and upland streams, as well as adjacent terrestrial environments. A prominent feature of freshwater estuaries is their diverse wetland vegetation which provides cover and food for estuarine animals. Because these plants slow the flow of water through the estuaries, they are important in erosion and sediment control by reducing the erosive effects of currents, by trapping sediments before they reach the open lake, and by attenuating lake-generated waves that enter the estuaries. The same vegetation provides a natural pollution abatement mechanism by filtering and absorbing excess nutrients and toxic substances, thereby reducing the loading of these materials to the lakes. The important functions and values of freshwater estuaries, with particular reference to Old Woman Creek estuary, are outlined in the following paragraphs.

FISH HABITAT

Freshwater estuaries are important sources of nutrition for commercial, sport, and forage fisheries living in the Great Lakes. Emergent wetland plant communities of freshwater estuaries are among the most botanically productive areas on earth, rivaling salt marshes, tropical rain forests, and intensively cultivated areas. The net primary productivity of these plants range from 3,000 to 8,500 $g/m^2/yr$ (Westlake 1963). When wetland plants die, bacteria and fungi transform the plant tissues into fragments of food and nutritionally-rich detritus which are carried into the estuary basin and open waters of the lake, where many fish and invertebrate species are dependent on this debris. In addition, estuarine wetlands provide protected nursery grounds for young-of-the-year (YOY) fish. Thibault (1985) observed YOY and juvenile Lake Erie fish species in Old Woman Creek estuary and concluded that these fishes episodically reproduce in the estuary and use it for a nursery ground. Hoffman (1985) noted that the diversity and large numbers of these fish reflect the importance of the estuary as a spawning and nursery area for lake species.

WATERFOWL AND OTHER WILDLIFE HABITAT

Freshwater estuaries provide essential breeding, nesting, feeding, and predator escape habitats for many forms of waterfowl, other birds, mammals, reptiles, amphibians, and invertebrate animals. The land-water interface of these estuaries, including upland buffer areas, is among the richest wildlife habitats in the world (Kusler 1983). This diversity and concentration of wildlife is a result of: (1) ample water which is needed by all life forms, (2) abundant and diverse vegetation which serves as a basis of food chains, and (3) adequate cover provided by aquatic, wetland, and shore vegetation. Freshwater estuaries also provide habitat for many threatened and endangered plant and animal species. Old Woman Creek estuary and its environs support 14 species of rare plants, 12 species of rare fish, and 28 species of rare birds listed by the Ohio Department of Natural Resources.

FOOD, FUR, AND TIMBER PRODUCTION

Considering their high natural productivity, estuarine wetlands have unrealized food production potential for harvesting marsh vegetation and for aquaculture. Kusler (1983) reported that *Typha* (cattails) hold an enormous potential for production of protein; one hectare can yield up to 60 tons of cattail biomass and produce 14 tons of cattail flour. Aquaculture for fishes such as *Cyprinus* (carps) and *Ictalurus* (catfishes) is promising in freshwater estuaries. Although beaver, mink, otter, weasel, and skunk are occasionally taken from Great Lakes coastal wetlands, the main furbearers in terms of total pelt value are muskrat and raccoon. Muskrat densities and pelt qualities are highest in cattail marshes, while raccoons commonly inhabit wooded bottomlands near waterways (Herdendorf et al. 1981a,b). Forested wetlands are an important source of timber despite the logistical problems involved in removing felled trees from swamps.

FLOOD CONVEYANCE AND STORAGE

Floodplain formation is a process which takes place during floods to create a natural conveyance configuration for flood waters and sediment. Estuarine wetlands, floodplains, and channels often form natural floodways that convey flood waters from upstream tributaries to the main estuary basin and the open lake, thereby reducing the inundation of upstream areas.

Estuarine basins store water during times of flood and often release it slowly to the open lake, depending on conditions at the estuary mouth. For example, a one meter rise in water level above the mean level of Old Woman Creek estuary increases the storage capacity of the estuary by nearly one-half million cubic meters of water (Herdendorf and Hume 1991). At mean water level, the estuary has an area of approximately 211,000 m^2 and a storage capacity of 38,600 m^3, whereas at one meter above mean, the area is 593,400 m^2 and the volume is 523,600 m^3.

Barrier to Waves and Erosion

Estuarine barrier beaches and wetlands reduce the impact of storm waves and wind tides before they reach upland areas. Waves break on the sandy beaches and wetland plants attenuate wave height, dissipating much of the waves' energy. Many emergent wetland plants found in Old Woman Creek estuary, such as *Phragmites* (reeds), *Scirpus* (bulrushes) and *Typha* (cattails), have interconnected root systems. Their roots and thick rhizomes form gird-like mats which bind and protect estuarine soils against erosion.

Sediment and Pollution Control

Estuarine vegetation reduces flood flows and the velocity of flood waters, lessening erosion and causing sediment-laden waters to release their load. Estuarine plants filter and hold sediment that would otherwise enter the lake and cause siltation problems and habitat destruction. In addition to sediment, estuarine wetlands also protect water bodies from nutrients and other natural and anthropogenic pollutants. While macrophytic vegetation filters sediment, organic matter, and chemicals, micro-organisms utilize dissolved nutrients and decompose organic compounds. Heath (1986) determined that water leaving Old Woman Creek estuary had a 77% lower concentration of soluble reactive phosphorus than water entering the estuary, while Klarer (1988) found that nitrate concentrations were reduced by 42%.

Water Supply and Groundwater Recharge

Freshwater estuaries are potentially important sources of surface water and groundwater, especially with the growth of urban centers and dwindling water supplies. Estuarine wetlands are effective in storing and purifying surface waters and serve as recharge sources for groundwater aquifers. Old Woman Creek estuary occupies a shallow basin in a pre-glacial valley that is buried under glacial till (Herdendorf 1966). Well drillers have found sand and gravel lenses in the till which serve as aquifers for domestic water supply. The aquifers are likely recharged by water percolating downward from the estuary.

Historical and Archaeological Values

Many freshwater estuaries are of historical and archaeological interest. American Indians and European-stock pioneers frequently selected Great Lakes estuaries for settlement because of the abundant wildlife, fish, and shellfish which they contained and the excellent boat harbors which they afforded. Old Woman Creek estuary is rich with historic Indian legends, including *The Legend of Minehonto*, the story of how the estuary got its name (Tuttle and Tuttle 1910). Archaeological excavations near Old Woman Creek (Shane 1981, 1992) reveal that peoples of the Palaeo-Indian (8,000 to 7,000 BC), Archaic (7,000 to 1,000 BC), and Woodland (1,000 BC to 1,600 AD) cultures occupied the creek valley and utilized its resources.

Education and Research Values

Freshwater estuaries provide educational opportunities for nature observation and scientific study, many projects of which have been conducted in conjunction with the Center for Lake Erie Area Research at The Ohio State University (Figure 1.3). In 1980 Old Woman Creek estuary was designated as a State Nature Preserve and at the same time as a National Estuarine Research Reserve, a site to serve as a field laboratory where scientists can study naturally-functioning systems and a place where

Figure 1.3. Fisheries research at Old Woman Creek estuary (Center for Lake Erie Area Research).

students and interested citizens can learn about estuarine ecology in a natural setting. As a transition zone between land and water, the site contains a variety of habitats including marshes and swamps, upland forests, open waters of the estuary, tributary streams, barrier beach, and nearshore Lake Erie. Old Woman Creek estuary is of particular regional and national value because it is the only National Estuarine Research Reserve on the Great Lakes and the only freshwater estuary in the national system.

RECREATION, OPEN SPACE, AND AESTHETIC VALUES

Recreational fishing and waterfowl hunting are popular leisure-time pursuits in freshwater estuaries and coastal marshes. Many sport and commercial species of fish and most waterfowl depend on these wetlands as sources of food and as spawning, breeding, and nesting areas. Even more popular is the recreational use of these areas for observing birds and wildlife with binoculars and cameras. Freshwater estuaries are areas of great diversity and beauty, providing open space area for recreational and visual enjoyment. Lands adjacent to scenic estuaries are often considered high-value real estate.

ECOLOGICAL OVERVIEW OF OLD WOMAN CREEK ESTUARY

Although much of Ohio's Lake Erie shoreline is highly developed, a few areas with significant natural features remain relatively undisturbed. One of these is a freshwater estuary located at the mouth of Old Woman Creek, about 5 km east of the city of Huron, Ohio. On the south shore of Lake Erie, this estuary lies near the southernmost point of the Great Lakes system. The Ohio Department of Natural Resources (ODNR) began the process of acquiring the property surrounding this estuary in 1975 (Figure 1.2) and applied to the National Oceanic and Atmospheric Administration (NOAA) for financial assistance to protect this unique natural area. In 1980 Old Woman Creek estuary received National Estuarine Research Reserve (NERR) designation. The NERR system is a network of federal, state, and community partnerships which serve to promote informed management of our nation's estuarine and coastal habitats through linked programs of scientific understanding, public education, and stewardship. The 230-hectare Old Woman Creek State Nature Preserve and National Estuarine Research Reserve (hereafter referred to as the Reserve) serves as a field laboratory where scientists study naturally functioning systems and is a place where students and the public learn about estuarine ecology in a natural setting.

As a transition zone between land and water, Old Woman Creek estuary and its immediate environs contain several distinct habitats, including woodlands, a prairie remnant, creek valley, swamp forest, marshes, wooded coves, open waters of the estuary, an island, barrier beach, and nearshore Lake Erie (Figure 1.4). The estuary is the drowned mouth of a relatively small tributary to Lake Erie. As the result of lake wave action and littoral drift, a barrier beach has formed at the mouth which bars off the estuary for extended periods. The barrier is periodically broken by storm flow from the watershed, but occasionally Lake Erie storm surges spill over the bar and into the estuary.

Old Woman Creek drains 69 km^2 of primarily agricultural land (Figure 1.5). The headwater tributaries of Old Woman Creek originate on a till plain surface

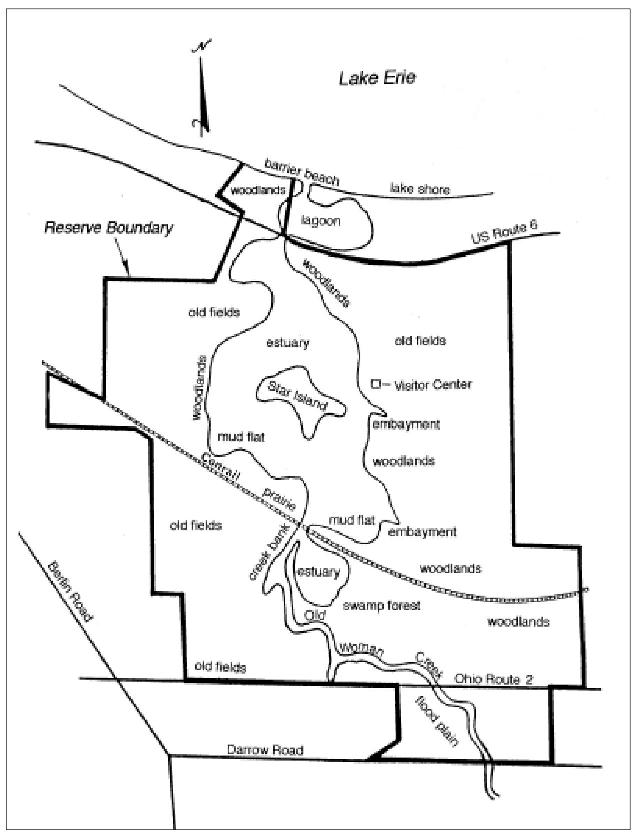


Figure 1.4. Old Woman Creek National Estuarine Research Reserve showing habitats.

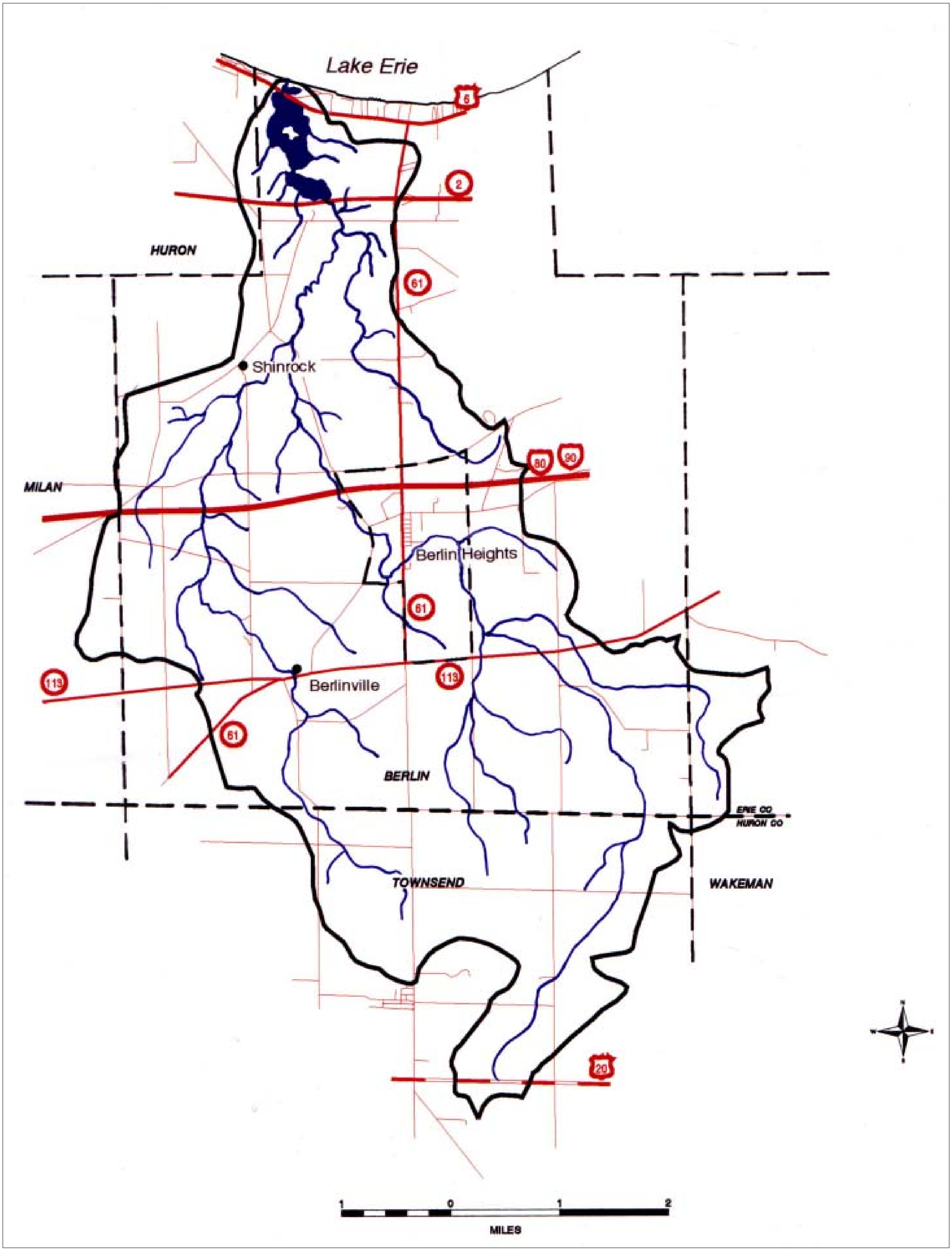


Figure 1.5. Old Woman Creek watershed.

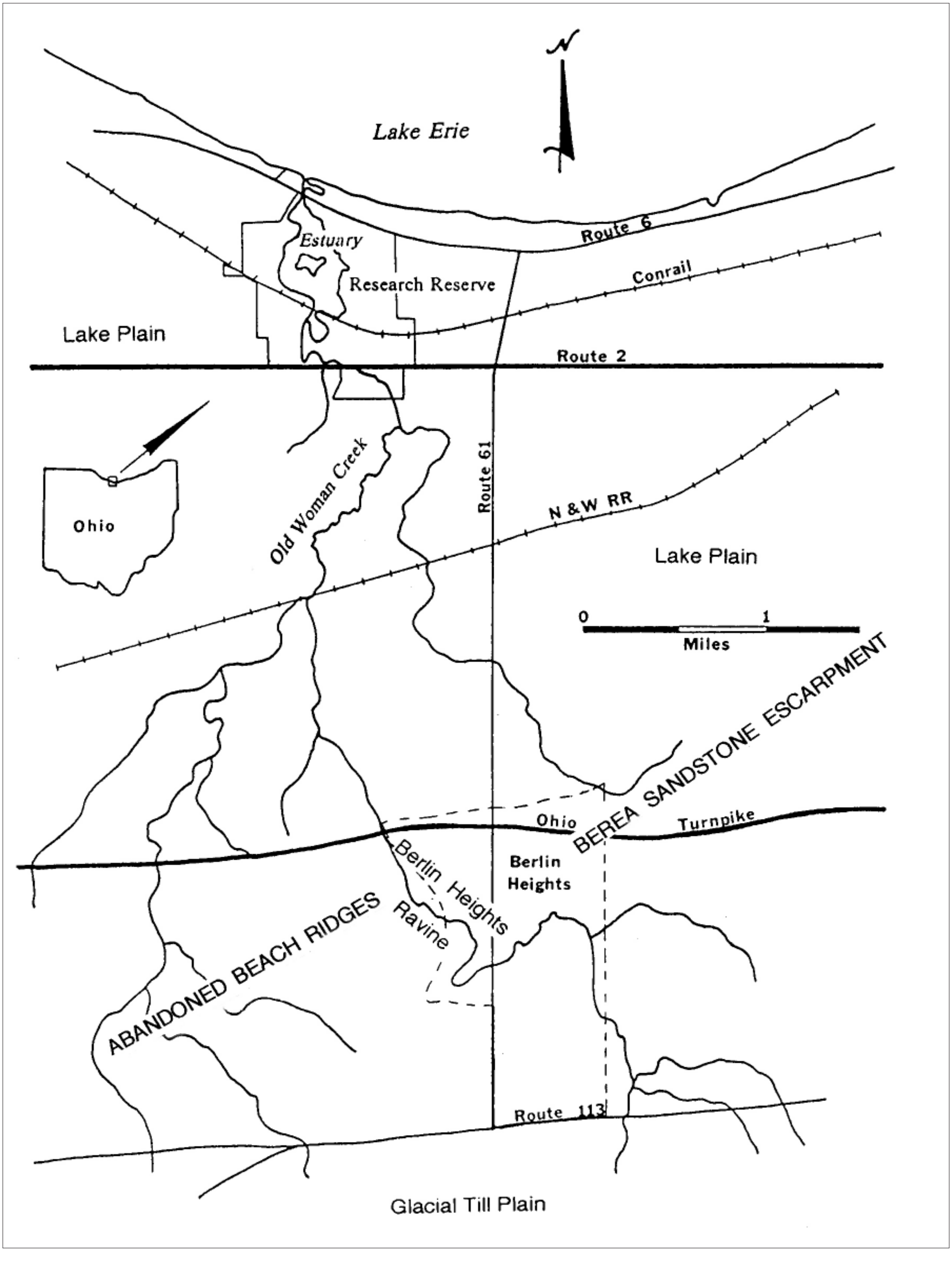


Figure 1.6. Northern portion of Old Woman Creek watershed showing tributary pattern and geomorphic features.

at an elevation of approximately 270 m above sea level. The creek empties into Lake Erie 24 km downstream, dropping 96 m as it flows over the rolling till plain, through the high Berea escarpment, and down the gentle lake plain (Figure 1.6). Two main branches, east and west, originate in the till plain, cut independently through the sandstone escarpment, and join on the lake plain about 2 km south of the estuary. Floral habitats within the watershed include hardwood forests, meadows, ravines, sandstone hills, abandoned beach ridges, creek banks, floodplains, active and old agricultural fields, and rights-of-way margins.

As a member of the NERR system, the mission of the Reserve is to ensure the long-term protection of Old Woman Creek estuary and to provide for long-term research, monitoring, and education through comprehensive on-site administration and management. To achieve this mission, four goals have been established for the Reserve: (1) establish, manage and maintain a protected area typical of a Great Lakes estuary within the national network that represents the diverse biogeographical and typological estuarine ecosystems of the United States, (2) mobilize federal, state, and community resources to mutually define and achieve goals for coastal protection and wise uses of coastal attributes, (3) design and initiate a comprehensive program of research and monitoring to address estuarine science questions and coastal management issues, and (4) develop compelling educational, interpretive, and information transfer programs based on solid scientific principles to strengthen the understanding, appreciation, stewardship, and enlightened use of estuaries, coastal habitats, and associated watersheds (Wright 1981, 1983, 2000).

SETTING AND ATTRIBUTES

The Old Woman Creek estuary ecosystem is among the few remaining natural functional coastal wetlands on the Ohio shore of Lake Erie. As discussed earlier, coastal wetlands like the estuary of Old Woman Creek perform many valuable functions such as water quality enhancement, flood and erosion control, and critical fish and wildlife habitat. Old Woman Creek Reserve is located at the drowned mouth of a small tributary to Lake Erie. The estuarine wetlands consists of 60 hectares (150 acres) that extend 2.1 km (1.3 mi) south of the Lake Erie shore. The estuary is 0.34 km (0.21 mi) wide at its widest portion. Depths range up to 3.6 m (11.8 ft) in the inlet channel, but most of the estuary is less than 0.5 m (1.5 ft) deep. Water retention time in the estuary is generally less than a day except at times when the mouth is barred across, which occurs over 40% of the time. The estuary's outlet mouth may be closed off for extended periods as the result of wave action and the formation of a barrier beach. The barrier is usually broken by storm flow from the 69 km^2 watershed, but infrequently, dramatic Lake Erie seiches spill over the bar and into the estuary.

The diversity of habitats present within Old Woman Creek watershed contribute to a wide variety of plant communities, each comprised of a distinctive flora. Over 800 terrestrial and aquatic species of vascular plants have been identified in the watershed and more than half of which are found within the boundaries of the Reserve, including floating-leaved plants, wildflowers, grasses, sedges, shrubs, and trees. Aquatic and wetland habitats include open water areas, mud flats, embayment marshes, swamp forests, and a variety of shoreline types. The wetlands of the estuary are essential to the survival of such important aquatic plants as the American water lotus, arrowhead, duckweed, cattails, bulrushes, water lilies, and many others. Through 1999 the lower estuary was dominated by the American water lotus and to a lesser extent sago pondweed, coontail, and white water lily. The mud flats, which have expanded because of the lower water levels since 1999 are characterized by grasses, the common reed, cattail, marsh mallow, bur-reed, and water smartweed. During periods of high lake level, and for a time following such periods, vegetation can be sparse on these flats. Shoreline plants include buttonbush, common reed, dogwood, blue flag, river bulrush, cattails, and arrowhead.

Terrestrial habitats in the Reserve are largely former agricultural fields in various stages of succession and some hardwood forests. Old field plant communities are composed primarily of successional species such as ragweed, aster, goldenrod, sumac, wild carrot, and several grasses. A white oak-shagbark hickory forest predominates on the relatively steep banks of Star Island, in the center of the estuary, with sassafras as a major associate. Elsewhere surrounding the estuary, the uplands area exhibit mixed hardwood forests of oak, hickory, maple, cherry, ash, and others with an understory of shrubs, small trees, and abundant wildflowers. Herbaceous associates of the forest communities include large white trillium, may-apple, violets, trout-lilies, cardinal flower and other woodland species. Near the railroad corridor an open prairie exhibits big bluestem, Indian grass, whorled rosinweed, butterfly-weed, ladies'-tresses, and bush clover. The xeric conditions of the barrier beach support Russian thistle, cocklebur, witchgrass, inland searocket, and velvet-leaf.

Plankton and periphyton, the microscopic plants and animals floating in the water, on the bottom, and attached to plants, are found in all aquatic habitats in the Reserve. They play a major role in the estuarine ecosystem and, along with bacteria, are considered the foundation of the aquatic food web. Phytoplankton, the primary producers, are represented by over 500 algal species in the estuary. Zooplankton, the primary consumers, number over 300 species, more than 200 of which are single-celled protozoans. The bottom or macro-benthic community of animals in the estuary is represented by 13 animal phyla, composed of over 200 species. Plankton and the benthos are essential and major food items for larval, juvenile, and many adult fishes, as well as waterfowl and other birds.

Old Woman Creek is a critical spawning and nursery habitat for many fishes. In the watershed streams, estuary, and adjoining waters of Lake Erie, 121 species of fishes have been identified, over 50 of which spend a portion of their life cycle in the estuary. Several of these species are important to the Lake Erie sport and commercial fisheries (white and black crappie, bluegill, channel catfish, bullheads, and carp), or are forage for these species (gizzard shad and shiners).

Old Woman Creek also provides excellent habitat for many wetland-dependent, vertebrate species. Researchers have identified 27 amphibians, 25 reptiles, and 42 mammals within the watershed. Frogs, turtles (particularly snapping turtles, Figure 1.7), snakes, and muskrats are the most common types in the vicinity of the estuary.

Over 250 species of birds have been recorded in the vicinity of Old Woman Creek Reserve. Numbers are greatest in the spring and fall when migrating birds stop to rest and feed before or after crossing Lake Erie. Old Woman Creek is located near the intersection of the Atlantic and Mississippian flyways which further contributes to the diversity of birds utilizing the estuary, streams of the watershed, and nearshore Lake Erie. Waterfowl, shorebirds, hawks, and warblers in large concentrations stop over at the Reserve during spring migration periods, mid-summer, autumn, and early

*Figure 1.7. Snapping turtle (*Chelydra serpentina*) in Old Woman Creek estuary (Glen E. Bernhardt).*

*Figure 1.8. Bald eagle (*Haliaeetus leucocephalus*) at Old Woman Creek estuary (artist: Jim Glover).*

winter months. The estuary is also frequented by bald eagles during spring and fall migration, in summer following fledging of young birds, and through the winter as long as open water is present. Over 40 eagles have been observed at one time over the estuary. In 1995 the first nesting of a pair of bald eagles occurred in the Reserve (Figure 1.8), with one eaglet being hatched and successfully reared at the edge of the estuary. In 1997, 1998, and 2000 two eaglets were produced each year; in 1999 the pair reared three.

ADMINISTRATION AND RESERVE STAFF

The establishment of the National Estuarine Research Reserve (NERR) system was the result of studies initiated in the 1960s when the importance of estuaries and other coastal wetlands were first beginning to be appreciated. Ecologists working along the marine coasts found that wetland areas, when permitted to function in their natural condition, furnish us with many benefits at little or no cost. To enumerate a few: estuaries filter pollution, protect coastal areas from flooding, and provide critical habitat for commercial and sport fish species. Likewise, scientists studying the Great Lakes discovered that within embayments, where steams flow into large lakes, similar natural functions occur.

The Coastal Zone Management Act of 1972 (CZMA), as amended, delegates the responsibility for managing our nation's coastal zone to NOAA, an agency of the U.S. Department of Commerce. Under Section 315 of the CZMA, the Secretary of Commerce is authorized to make financial assistance awards to coastal and Great Lakes states toward the purchase of estuaries, coastal wetlands, and uplands surrounding estuaries for protection and associated research and educational programs. These estuaries are then designated as National Estuarine Research Reserves. As of the year 2004, there are 26 Reserves in the system; Old Woman Creek estuary is the only NERR in the Great Lakes region and the only freshwater estuarine Reserve in the system (Figure 1.9).

The Division of Natural Areas and Preserves, within ODNR, is the state agency charged with establishing and managing state nature preserves (Ohio Revised Code, Chapter 1517). As such, this division is the logical choice to perform the long-term management of Old Woman Creek Reserve in concert with NOAA guidelines. NERR programs—research, monitoring, education, and outreach, as well as facilities operation and administration—are carried out by an on-site Reserve staff and volunteers. The blueprint that guides the operation of the Reserve and future development is contained in the *Management Plan for Old Woman Creek National Estuarine Research Reserve and State Nature Preserve* (Wright 2000).

The full-time staff of the Reserve includes a program administrator, a research coordinator, and an education coordinator. This staff is supplemented by part-time technical, clerical, and custodial workers, seasonal interns, and a volunteer corps. The program administrator is responsible for the overall operation and fiscal management of the Reserve. The research coordinator designs, conducts, and/or supervises specific research and monitoring projects in support of the Reserve's mission, as well as coordinating all other research and monitoring activities in the Reserve. Research at the Reserve is further supported by a cadre of visiting scientists from educational institutions, government agencies, and private organizations. The education coordinator develops, supervises, and conducts educational programs focusing on Old Woman Creek estuary and watershed, and on the national NERR program, for educators, students, resource managers and policy makers, and the general public.

Adjunct to the Reserve staff is the Old Woman Creek State Nature Preserve Manager who carries out the Reserve's resource protection program, including habitat management, invasive species control, and law enforcement. As time permits, the Manager also provides field assistance for research and educational activities. To aid in the preparation and implementation of specific plans concerning the Reserve, an advisory council is appointed by the Director of the Ohio Department of Natural Resources. The Reserve is further supported by an active, non-profit, fund-raising organization, "The Friends of Old Woman Creek, Inc.," which received 501-C-3 status in 1998.

Figure 1.9. Aerial view of Old Woman Creek estuary (Charles E. Herdendorf).

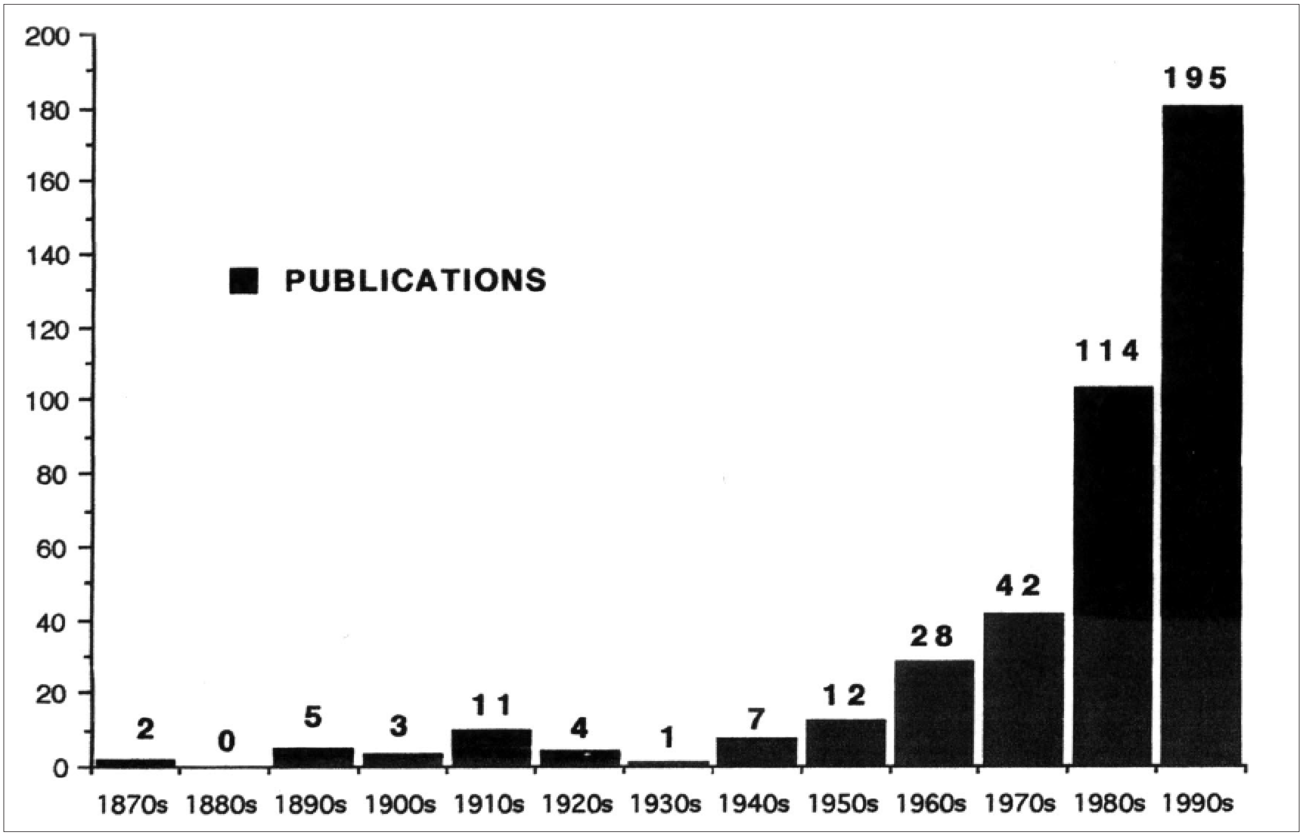


Figure 1.10. Number of publications resulting from research conducted in the vicinity of Old Woman Creek.

RESEARCH AND MONITORING PROGRAM

Stemming from the goals of the NERR system, research on estuarine habitats and processes has emerged as a major focus. At Old Woman Creek Reserve the research and monitoring program is designed to facilitate understanding of Great Lakes estuarine systems and monitor the baseline conditions of Old Woman Creek estuary. This program is intended to generate and supply information to resource agencies, governing bodies, and private sector organizations involved in coastal management and development. Coastal governments and policy-makers, as well as development-related firms, are encouraged to use NERR program results to make wise land use, waterway management and development decisions. Equally as important, the Great Lakes research community has access to a long-term database which describes estuarine conditions. Members of this community are invited to undertake research projects at the Reserve and to participate in a variety of research funding opportunities.

Table 1.1 is a time matrix of publications for various scientific disciplines that have contributed to knowledge of Old Woman Creek estuary, its watershed, and adjoining Lake Erie. Table 1.2 contains a chronological list of publication citations (author and date), by research category, for the over 400 studies tabulated in the matrix. Table 1.2 can serve as a useful index for locating papers in a particular field of interest (complete citations are given in the References Cited section).

Once the Ohio Department of Natural Resources made the decision to protect the estuary and promote research there in the mid-1970s, a dramatic increase followed in the number and variety of studies undertaken. In the one hundred years before the mid-1970s, only 92 documented research efforts, in 14 discipline categories, were undertaken that supplied information on the estuary or watershed. Whereas in the quarter century from 1975 to 2000, a total of 332 studies in 21 categories have been published. This is an increase from less than one publication each year before the Reserve concept was adopted, to over 12 scientific publications per year after the ODNR initiative. For the past five years, the rate has been over 20 published studies per year (Figure 1.10).

TABLE 1.1. RESEARCH AT OLD WOMAN CREEK ESTUARY AND WATERSHED

CATEGORY	1850-1899	1900-1949	1950-1959	1960-1969	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-2000	Total
•GEOLOGY	2	3	3	7	5	3	1	5	1	1	31
•SOILS & PEDOLOGY	0	0	1	1	1	0	1	0	3	2	9
•SEDIMENTOLOGY & GROUNDWATER HYDROLOGY	0	1	1	4	0	1	1	8	4	4	24
•HYDROLOGY, COASTAL PROCESSES, & PHYSICAL LIMNOLOGY	0	1	2	2	1	4	9	4	2	1	26
•CHEMICAL LIMNOLOGY & WATER QUALITY	0	0	0	0	0	0	2	8	6	11	27
•METEOROLOGY & CLIMATOLOGY	0	0	0	0	1	1	2	0	1	0	5
•MICROBIOLOGY	0	0	0	0	0	0	0	1	1	4	6
•PHYTOPLANKTON & LOWER PLANTS	0	8	0	3	0	0	2	3	4	9	29
•VASCULAR PLANTS	1	1	0	4	2	2	0	1	2	17	30
•ZOOPLANKTON	0	0	0	0	0	0	1	3	7	2	13
•BENTHIC INVERTEBRATES	0	0	0	0	0	0	3	1	7	7	18
•TERRESTRIAL INVERTEBRATES	0	0	0	0	0	0	1	0	0	5	6
•FISHERIES SCIENCE	0	0	1	0	2	1	8	5	7	11	35
•ORNITHOLOGY	0	1	0	0	0	0	2	2	2	1	8
•AMPHIBIAN & TERRESTRIAL VERTEBRATES	0	2	1	0	0	0	3	2	1	1	10
•LIMNOLOGY & ESTUARY/WETLAND ECOLOGY	0	0	0	1	1	0	3	9	11	8	33
•ARCHAEOLOGY & HISTORY	4	9	3	4	5	5	2	2	9	6	49
•LAND USE & WATER POLLUTION	0	0	0	1	1	2	1	5	3	8	21
•ENVIRONMENTAL MANAGEMENT & REHABILITATION	0	0	0	1	0	4	2	5	10	9	31
•METHODOLOGY & TECHNOLOGY DEVELOPMENT	0	0	0	0	0	0	1	1	1	2	5
•SCIENCE EDUCATION	0	0	0	0	0	0	1	3	0	4	8
TOTAL	7	26	12	28	19	23	46	68	82	113	424

TABLE 1.2. DOCUMENTED RESEARCH IN VICINITY OF OLD WOMAN CREEK

GEOLOGY
1. Newberry (1874); 2. Read (1878); 3. Leverett (1902); 4. Carney (1911); 5. Leverett and Taylor (1915); 6. Pepper et al. (1954); 7. Campbell (1955); 8. Forsyth (1959); 9. Hoover (1960); 10. Goldthwait et al. (1961); 11. Cranston and Linn (1962); 12. Herdendorf (1963b); 13. Herdendorf (1966); 14. Herdendorf (1967); 15. Hobson et al. (1969); 16. Janssens (1970); 17. Brant and Herdendorf (1972); 18. Herdendorf (1973); 19. Gardner (1974); 20. Murphy (1974); 21. Herdendorf and Struble (1975); 22. Herdendorf (1977); 23. Wolfgand and Gardner (1977); 24. Buchanan (1982); 25. Herdendorf (1986); 26. Lewis (1988); 27. Herdendorf (1989); 28. Pavey (1989); 29. Toten (1989); 30. Herdendorf and Hume (1991); 31. Bedrock Geology Mapping Group (1997).

SOILS & PEDOLOGY
1. Wildermuth (1955); 2. Redmond and Hole (1967); 3. Redmond et al. (1971); 4. U.S. Dept. Agriculture (1986); 5. Ernst and Martin (1994); 6. Martin and Prebonick (1994); 7. Seamon (1994); 8. Evans and Seamon (1997); 9. Herdendorf (1997b).

SEDIMENTOLOGY & GROUNDWATER HYDROLOGY
1. Stout et al. (1943); 2. Cummins (1959); 3. Hartley (1961a); 4. Stein (1962a); 5. Stein (1962b); 6. Hobson et al. (1969); 7. Herdendorf (1976); 8. Buchanan (1982); 9. Frizado et al. (1986); 10. Hartzell (1986); 11. Mancuso (1986); 12. Walker (1986); 13. Woods (1987); 14. Matisoff and Eaker (1989); 15. Mitsch et al. (1989); 16. Reeder (1989); 17. Clarke (1990); 18. Matisoff and Eaker (1992); 19. Reeder and Eisner (1994); 20. Seamon (1994); 21. Brush and Brush (1997); 22. Evans and Seamon (1997); 23. Tomaszak et al. (1997); 24. Matisoff et al. (1998).

HYDROLOGY, COASTAL PROCESSES, & PHYSICAL LIMNOLOGY
1. U.S. Army Corps of Engineers (1946); 2. U.S. Army Corps of Engineers (1953); 3. Goodman (1956); 4. Herdendorf (1963b); 5. Cross (1967); 6. Brant and Herdendorf (1972); 7. Herdendorf (1975); 8. Resio and Vincent (1976); 9. U.S. Army Corps of Engineers (1977); 10. Bedford et al. (1978); 11. Carter and Guy (1980); 12. Worthy (1980); 13. Bedford, Fischer, Mattox, and Herdendorf (1983c); 14. Bedford, Lindsay, Mattox, and Herdendorf (1983a); 15. Bedford, Prater, Mattox, and Herdendorf (1983d); 16. Bedford, Worthy, Mattox, and Herdendorf (1983b); 17. Fischer (1983); 18. Lindsay (1983); 19. Prater (1983); 20. Klarer (1988); 21. Bedford (1989); 22. Mitsch et al. (1989); 23. Robb and Mitsch (1989); 24. Herdendorf and Hume (1991); 25. Krieger (1993); 26. Matisoff et al. (1998).

CHEMICAL LIMNOLOGY & WATER QUALITY
1. Krieger (1984); 2. Heath (1986); 3. Mancuso (1986); 4. Heath (1987) 5. Wickstrom (1988); 6. Klarer (1988); 7. Klarer and Millie (1989); 8. Krieger (1989); 9. Mitsch and Reeder (1989a); 10. Mitsch et al. (1989); 11. Robb and Mitsch (1989); 12. Mitsch and Reeder (1991); 13. Heath (1992a); 14. Heath (1992b); 15. Light (1992); 16. Mitsch and Reeder (1992); 17. Robb and Mitsch (1992); 18. Binion (1995); 19. Binion and Reeder (1996); 20. Lavrentyev et al. (1997); 21. Wickstrom and Corkran (1997); 22. Tomaszak et al. (1997); 23. Chin et al. (1998); 24. Francis et al. (1998); 25. Lavrentyev et al. (1998); 26. Everett et al. (1999); 27. Krieger (2000).

METEOROLOGY & CLIMATOLOGY
1. Miller (1971); 2. Ohio Edison Company (1977); 3. Herdendorf et al. (1986a); 4. Herdendorf et al. (1986b); 5. Bolsenga and Herdendorf (1993).

MICROBIOLOGY
1. Pfister and Frea (1989); 2. Kepner and Pratt (1993); 3. Kepner and Pratt (1996); 4. Lavrentyev et al. (1997); 5. Lavrentyev et al. (1998); 6. Herdendorf et al. (2000b).

PHYTOPLANKTON & LOWER PLANTS
1. Brain (1912); 2. Claassen (1912); 3. Fullmer (1912); 4. Claassen (1917); 5. Fink (1921); 6. Fullmer (1921); 7. Johnson (1929); 8. Wolfe (1940); 9. Snider and Andreas (1966); 10. Taylor (1967); 11. Taylor (1968); 12. Millie and Klarer (1980); 13. Klarer (1981); 14. Klarer (1983); 15. Klarer (1985); 16. Klarer (1989); 17.Havens (1991a); 18. Jensen (1992); 19. Klarer and Millie (1992); 20. Klarer and Millie (1994); 21. Binion (1995); 22. Sgro and Johansen (1995); 23. Binion and Reeder (1996); 24. Sgro and Johansen (1997); 25. Lavrentyev et al. (1998); 26. Franko and Whyte (1999); 27. Keller and Braun (1999); 28. Herdendorf et al. (1999a); 29. Klarer et al. (2000).

TABLE 1.2. DOCUMENTED RESEARCH IN VICINITY OF OLD WOMAN CREEK (cont'd)

VASCULAR PLANTS
1. Moseley (1899); 2. Easterly [~1950]; 3. Braun (1961); 4. Braun (1965); 5. Gordon (1966); 6. Gordon (1969); 7. Marshall and Stuckey (1974); 8. Marshall (1977); 9. Jones (1978); 10. Stuckey and Carr (1979); 11. Herdendorf (1987); 12. Feix and Wright (1992); 13. Klarer and Millie (1992); 14. Copperrider (1995); 15. Fisher (1995); 16. Franko and Whyte (1995a); 17. Franko and Whyte (1995b); 18. Windus (1995); 19. Bernhart (1996); 20. Degroft and Franko (1996); 21. Whyte (1996); 22. Jones (1997); 23. Kooser et al. (1997); 24. Phillips (1997); 25. Vance and Franko (1997); 26. Whyte et al. (1997); 27. Wickstrom and Corkran (1997); 28. Martz and Franko (1998); 29. Franko and Whyte (1999); 30. Herdendorf et al. (1999a).

ZOOPLANKTON
1. Klarer (1981); 2. Krieger (1985); 3. Bur et al. (1986); 4. Klarer (1989); 5. Bur and Klarer (1991); 6. Havens (1991a); 7. Havens (1991b); 8. Havens (1991c); 9. Havens (1991d); 10. Krieger and Klarer (1991); 11. Kepner and Pratt (1993); 12. Kepner and Pratt (1996); 13. Herdendorf et al. (2000b).

BENTHIC INVERTEBRATES
1. Miller (1982); 2. Ingold et al. (1984); 3. Miller et al. (1984); 4. Klarer (1989); 5. Lewis (1990); 6. Heady (1992); 7. Krieger (1992); 8. Krieger and Klarer (1992); 9. Kepner and Pratt (1993); 10. Delorme (1994); 11. Garono and Kooser (1994); 12. Krieger and Klarer (1995); 13. Kobza (1997); 14. Phillips and Nemire (1999); 15. Trisler (1999); 16. Harvill (2000); 17. Herdendorf et al. (2000b); 18. Kobza and Harvill (2000).

TERRESTRIAL INVERTEBRATES
1. Perry and Perry (1983) 2. Gray et al. (1997); 3. Phillips (1998); 4. Phillips and Nemire (1999); 5. Trisler (1999); 6. Herdendorf et al. (2000b).

FISHERIES SCIENCE
1. Trautman (1957); 2. Van Meter and Trautman (1970); 3. Ohio Division of Wildlife (1974); 4. Ohio Edison Company (1977); 5. Ohio Division of Wildlife (1980); 6. Trautman (1981); 7. Goodyear et al. (1982); 8. Ohio Division of Natural Areas and Preserves (1983); 9. Owen et al. (1983); 10. Crites et al. (1984); 11. Emmons (1984); 12. Thibault (1984); 13. Hoffman (1985); 14. Thibault (1985); 15. Johnston and Baumann (1989); 16. Rotenberry, Emmons, and Hardman (1989) 17. Rotenberry, Bergin, and Steiner (1989); 18. Baumann et al. (1990); 19. Black and Baumann (1991); 20. Baumann (1992a); 21. Baumann (1992b); 22. Jude and Pappas (1992); 23. Wolfert and Bur (1992); 24. Johnson (1994); 25. Baumann and Harshbarger (1995); 26. Folmer et al. (1995); 27. Jude (1996); 28. Ohio Environmental Protection Agency (1996); 29. Heithaus and Grame (1997); 30. Thoma (1997); 31. Francis et al. (1998); 32. Herdendorf et al. (1999b); 33. Thoma (1999); 34. Micucci (2000); 35. Micucci and Stouder (2000).

ORNITHOLOGY
1. Jones (1909-1910); 2. Trautman (1981); 3. Wright (1991); 4. Peterjohn et al. (1987); 5. Peterjohn (1989); 6. Old Woman Creek Reserve (1990); 7. Peterjohn and Rice (1991); 8. Herdendorf et al. (1999b).

AMPHIBIAN & TERRESTRIAL VERTEBRATES
1. Conant (1938); 2. Walker (1946); 3. Conant (1951); 4. Gottschang (1981); 5. Patrick (1981); 6. Kraus and Schuett (1982); 7. Bernhart (1985); 8. Pfingsten and Downs (1989); 9. Boutis (1992); 10. Herdendorf et al. (1999b).

LIMNOLOGY & ESTUARY/WETLAND ECOLOGY
1. Cranston and Linn (1962); 2. Herdendorf (1974); 3. Herdendorf et al. (1981a); 4. Herdendorf et al. (1981b); 5. Klarer (1981); 6. Herdendorf (1987); 7. Herdendorf and Wilson (1987); 8. Herdendorf and Krieger (1989); 9. Mitsch (1989a); 10. Mitsch (1989b); 11. Mitsch and Reeder (1989b); 12. Reeder and Mitsch (1989a); 13. Reeder and Mitsch (1989b); 14. Robb (1989); 15. Herdendorf (1990); 16. Krieger et al. (1990); 17. Reeder (1990); 18. Herdendorf (1992); 19. Klarer et al. (1992); 20. Krieger et al. (1992); 21. Havens (1993); 22. Mitsch, Mitsch, and Turner (1994); 23. Mitsch, Reeder, and Robb (1994); 24. Reeder (1994); 25. Robbins et al. (1994); 26. Binion (1995); 27. Binion and Reeder (1996); 28. Gray et al. (1997); 29. Tomaszek et al. (1997); 30. Chin et al. (1998); 31. Martz and Franko (1998); 32. Franko and Whyte (1999); 33. Thoma (1999).

TABLE 1.2. DOCUMENTED RESEARCH IN VICINITY OF OLD WOMAN CREEK (cont'd)

ARCHAEOLOGY
1. Mills (1914); 2. Shane (1967a); 3. Shane (1967b); 4. Shane (1967c); 5. Brose (1976); 6. Strothers and Yarrnell (1977); 7. Seeman and Bush (1979); 8. Shane (1981); 9. Bowen (1988); 10. Abel and Haas (1991); 11. Strothers (1991); 12. Strothers and Abel (1991); 13. Shane (1992); 14. Stothers and Abel (1993); 15. Abel (1994); 16. Cavender and Bowen (1994); 17. Stothers et al. (1994); 18. Stothers (1996); 19. Bowen (1997); 20. Stothers and Schneider (1997); 21. Stothers and Abel (1998); 22. Stothers et al. (1998).

HISTORY
1. Barber (1896); 2. Purdee (1896); 3. Wadsworth (1896); 4. Williams (1897); 5. Howe (1902); 6. Tuttle and Tuttle (1910); 7. Peeke (1916); 8. Peeke (1925); 9. Ryan (1928); 10. Hatcher (1945); 11. Vietzen (1945); 12. Hatcher (1949); 13. Downes (1952); 14. Mackiewicz (1959); 15. White (1959); 16. Frohman (1965); 17. Kubiak (1970); 18. Frohman (1971); 19. Adams (1972); 20. Frohman (1973); 21. Frohman (1974); 22. Frohman (1976); 23. White (1976); 24. Wendt (1984); 25. Hirsimaki (1988); 26. Herdendorf and Schuessler (1993); 27. Niederhofer and Stuckey (1998).

LAND USE & WATER POLLUTION
1. Erie Regional Planning Commission (1967); 2. Erie Regional Planning Commission and Parker, Rogers & Associates (1970); 3. Gedeon (1977); 4. Ohio Edison Company (1977); 5. Herdendorf 1980); 6. Holly (1986); 7. U.S. Dept. Agriculture (1986); 8. Klarer (1988); 9. Klarer and Millie (1989); 10. Krieger (1989); 11. Wright et al. (1991); 12. Jude et al. (1992); 13. Mitsch (1994); 14. Binion (1995); 15. Binion and Reeder (1996); 16. Gregory (1996); 17. Echelberger (1997); 18. Herdendorf (1997a); 19. Matisoff et al. (1998); 20. Thoma (1999); 21. Krieger (2000).

ENVIRONMENTAL MANAGEMENT & REHABILITATION
1. Herdendorf (1963a); 2. Ohio Dept. Natural Resources (1975); 3. U.S. Dept. Commerce (1975); 4. U.S. Dept. Commerce (1977); 5. Hanselmann and Vogel (1978); 6. Wright (1981); 7. Wright (1983); 8. Wright et al. (1985); 9. Wright et al. (1986); 10. Wright et al. (1987); 11. Wright et al. (1988); 12. Wright et al. (1989); 13. Reeder and Mitsch (1990); 14. Wright et al. (1990); 15. Wright et al. (1991); 16. Mitsch (1992a); 17. Mitsch (1992b); 18. Mitsch (1992c); 19. Mitsch (1992d); 20. Wright et al. (1992); 21. Wright et al. (1993); 22. Wright et al. (1994); 23. Benoit (1995); 24. Courter (1995); 25. Wright et al. (1995); 26. Wright et al. (1996); 27. Wright et al. (1997); 28. Wright et al. (1998); 29. Wright et al. (1999); 30. Herdendorf et al. (2000a); 31. Wright (2000).

METHODOLOGY & TECHNOLOGY DEVELOPMENT
1. Van Evra (1983); 2. Roush et al. (1989); 3. Krieger (1993); 4. Everett et al. (1999); 5. Thoma (1999).

SCIENCE EDUCATION
1. Olson (1983); 2. Lahm (1986); 3. Pless (1987); 4. Fortner et al. (1988); 5. Courter (1995); 6. Niederhofer (1997); 7. Niederhofer and Stuckey (1998); 8. Herdendorf et al. (2000a).

Since its inception, the research program at Old Woman Creek Reserve has concentrated on describing the various communities within the estuary and watershed, and identifying major processes that impact the estuary. This has resulted in a database that can be incorporated by future researchers in developing more integrated investigations that relate the significance of watershed functions to estuarine functions and, in turn, relate the significance of these coastal wetlands to Lake Erie.

Research undertaken at Old Woman Creek Reserve is classified into two groups: (1) studies conducted under NERR or ODNR auspices and (2) independent studies. The first group of investigations are highly focused on specific research needs as identified by the Reserve staff, ODNR, or NOAA. Studies of the second category are less focused on these needs, but are still relevant to understanding the freshwater estuarine ecosystem. The success of the research program is dependent on the ability of the Reserve staff to encourage the research community to utilize the site for study. The approach used to encourage outside research is to provide the scientific community with: (1) direction on Old Woman Creek Reserve research needs, (2) fundamental data necessary to develop a research plan, (3) opportunity to conduct research in a limited access area, and (4) on-site laboratory facilities and housing accommodations. As a state nature preserve, as well as a NERR site, large-scale manipulative research projects at Old Woman Creek Reserve are strongly discouraged. However, certain manipulation-type projects that do not significantly alter the estuarine system may be permitted. The long-term objective of the research program is to synthesize the cumulative results of these diverse projects into a comprehensive understanding of the freshwater estuarine system.

The first NERR regional conference was held at Old Woman Creek Reserve in 1989: *Priorities for Great Lakes Coastal Wetlands Research*. The conference was attended by 67 wetlands scientists, coastal managers, and government agency personnel from Canada and the United States. The results of this workshop were published as an Old Woman Creek NERR technical report (Krieger et al. 1990); workshop participants recommended that research and administrative efforts be focused on: (1) energy flow in coastal wetlands, (2) physical processes, (3) biogeochemical cycles, (4) applied problems, (5) the link between research, management, and education, (6) methodology development, and (7) infrastructure enhancement. More recently emphasis has also been placed on pollution inputs from non-focused or non-identifiable sources and the restoration of habitats that have been impacted by cultural activities.

Studies of the physico-chemical and geological characteristics of the estuary provide an understanding of surface water quality, especially as it relates to storm activity. However, relatively little is known of groundwater abundance or quality. Groundwater will become an increasingly important factor as urbanization increases in the Old Woman Creek watershed. Physical studies suggest that a paradox exists in the estuary, and most likely in other Great Lakes estuaries. On one hand, paleogeomorphic studies demonstrate that the lower reach of Old Woman is an aggrading stream, actively building up its channel and flood plain by being supplied with more load than it is capable of transporting. Thus, the estuary should fill in quickly – causing it to undergo the typical "aging" process that is common for interior wetlands. On the other hand, recent studies indicate the estuary is in a long-term steady state, neither aggrading or eroding, but merely experiencing short-term variations. Further work is needed to sort out this apparent paradox.

Several surveys have described various components of the biotic communities in the Reserve (Herdendorf et al. 2001a,b,d and Klarer et al. 2001). The emphasis has been placed on aquatic species in the open waters of the estuary, but terrestrial species living near the shore and in upland areas have received some attention. The rapidly expanding field of aquatic microbiology is producing techniques that will allow the identification and enumeration of specific bacterial populations and their functional significance. A more complete understanding of the role of bacteria in the estuarine ecosystem is a critical research need. Future studies are being formulated that will address the rate of detrital production, the role of detritus and humic compounds in the estuary, detrital processing, and the relationship of detritus to energy/ nutrient flow in the estuary and to the availability of toxic substances.

The monitoring plan for Old Woman Creek Reserve follows the phased approach outlined in 1989 by NOAA for all the sites in the NERR system. Basically the plan has three sequential phases: (1) environmental characterization, including studies necessary for inventory and comprehensive site description purposes, (2) synthesis of data and other information, and (3) implementation of a systematic, long-term monitoring program focused on selected parameters of particular importance to Old Woman Creek estuary and watershed. The goal of the monitoring effort at the Reserve is to develop a data bank of basic information about the estuary, its watershed, and the adjacent nearshore portion of Lake Erie. The design is such that long-term, subtle changes can be detected. The data bank also provides potential researchers with the background necessary to develop viable research projects. This Site Profile is a contribution toward the data synthesis objective.

Monitoring of the chemical components of the estuary and upstream waters was initiated in 1980 and has been in operation for the past 20 years (Figure 1.11). Benchmark monitoring sites include: (1) upstream creek, (2) upper reach of the estuary, (3) mouth of the estuary, and (4) surf zone of Lake Erie. The selection of parameters has been modified from time to time to meet specific needs, but basic water quality factors, major biological nutrients, and certain metals have been continuous components of the monitoring program.

Figure 1.11. Water quality monitoring in Old Woman Creek estuary (Gene Wright).

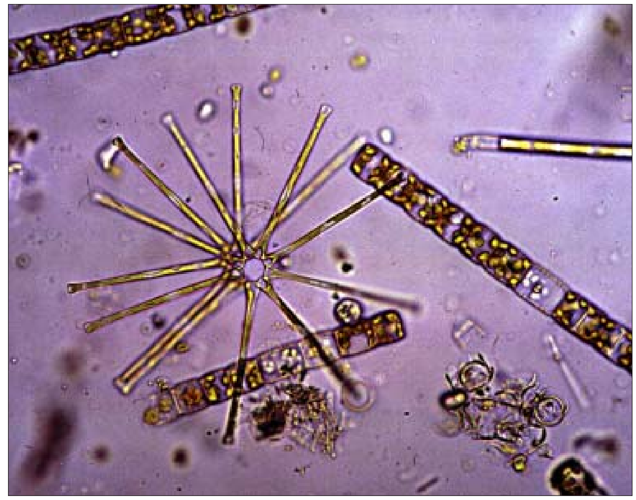


Figure 1.12. Photomicrograph of plankton from Old Woman Creek estuary (David M. Klarer).

Phytoplankton samples are collected in conjunction with the water quality program (Figure 1.12). The objective of this effort is to inventory the algal flora and to determine the temporal and spatial distribution patterns of the major algal species in the estuary in relation to environmental conditions (Klarer et al. 2001). Species lists, distribution records, and basic seasonal patterns for aquatic and terrestrial macrophytes, zooplankton, benthic protozoans and macro-invertebrates, terrestrial invertebrates, fish, amphibians, reptiles, birds, and mammals have been developed by numerous researchers in the course of their investigations (Herdendorf et al. 2001b,c,d).

In conjunction with the U.S. Geological Survey, water level recorders were maintained at 3 sites for 10 years; such records permit the determination of water mass movements into and out of the estuary (Krieger 1993). A hydrographic survey was conducted in 1990, which resulted in the preparation of a detailed bathymetric map, hypsographic curves, and water storage calculations (Herdendorf and Hume 1991). Selected data lines from the survey can be repeated periodically to determine sedimentary processes, such as erosion and accretion in the estuary.

The impact of cultural activities within the watershed on the vital processes in the estuary is another area where several research and monitoring projects have focused. Different land use activities result in different stresses on the stream and the estuary. Since the completion a major highway corridor at the southern edge of the Reserve in the late 1980s, new developments and other land use changes have ensued that will undoubtedly have both short-term and long-term effects on the estuary. The development of reliable predictive models to aid in determining the impact of future land use change on estuarine systems will continue to be fruitful research and monitoring efforts.

EDUCATION AND INFORMATION TRANSFER

The education and outreach program at Old Woman Creek Reserve is an integral part of a national network for interpreting and disseminating information about and appreciation of estuarine processes. The program also explores new techniques and approaches to estuarine education. A primary goal of the education program is to facilitate the link between the results of research, through the translation of those results, to individuals and groups who affect the future of coastal resources.

Old Woman Creek Reserve offers Lake Erie's coastal residents and visitors unparalleled opportunities to learn about a Great Lakes estuary and its watershed. The Reserve's educational programs are designed to promote public awareness and understanding of estuarine resources, habitats, and ecosystems. The Reserve is envisioned as a natural classroom for science instruction. Programs range from audio-visual presentations, interpretive field trips and guided tours, to guest lectures, educator workshops, and technical training seminars for professionals involved in coastal management issues. These activities are supplemented by interpretive materials, visitor center exhibits, informational publications, and access to trails and observation decks.

Outreach activities which focus on estuarine ecology have been developed in association with school systems, colleges and universities, civic and environmental organizations, and various other groups and institutions. Particular emphasis is placed on: (1) training students and educators in concepts of estuarine ecology and (2) timely interpretation of pertinent scientific knowledge and research results, in a useful format, for resource managers responsible for creating and implementing coastal management strategies.

The education program has the lead responsibility for maintaining the reference library, publishing informational and interpretive brochures, and presenting exhibits in the visitor center. Examples of exhibits that have been displayed at the center demonstrate the link between research projects and education are: (1) *The Estuary*, (2) *The Creek*, (3) *Barrier Beach and Lakeshore*, (4) *The Watershed*, (5) *The Ice Invasion*, (6) *Lake Erie's Natural Filter*, (7) *Resource Use/Archaeology*, (8) *Habitat for Birds*, and (9) *Meteorology*. The visitor center exhibits are designed to highlight research that is currently being conducted in the Reserve (Figure 1.13).

Figure 1.13. Example of exhibits demonstrating the ecology of the estuary displayed at the Ohio Center for Coastal Wetlands Study Visitor Center at Old Woman Creek (Gene Wright).

Since the opening of Old Woman Creek Reserve in 1980, over 150,000 visitors from all 50 states and over 20 foreign countries have been enriched by their experience at the estuary. The education program has organized workshops, courses and other outreach activities, presented by researchers, guest lecturers, and Reserve staff members. The development of a watershed stewardship program for local residents and the hosting of a national conference for NERR sites are examples of the breadth of the education program.

Figure 1.14. Ohio Center for Coastal Wetlands Study at Old Woman Creek SNP & NERR (David M. Klarer).

Facilities and Access

Housed in the Ohio Center for Coastal Wetlands Study, the headquarters for Old Woman Creek Reserve includes administrative offices, laboratories, reference library, classrooms, visitor center, and exhibits (Figure 1.14). Construction of this 745 m^2 (8,014 ft^2) facility, which overlooks the east bank of the estuary, was started in 1982, extended in 1985, and completed in 2003. Other on-site facilities include two dormatories, a boat house, maintenance shop, equipment storage building, and a trail system with an observation deck.

The laboratories at the Center are specialized for coastal wetlands research, yet flexible enough to accommodate a wide-array of projects. One of the laboratories was built and equipped as a chemical laboratory reflecting the importance placed on the water quality aspects of estuarine research. The classroom is used for educational programs, public forums, and workshops for students, educators, and environmental professionals. The library contains a complete set of the research reports and published papers resulting from projects undertaken at the Reserve, as well as technical journals, field guides, and other publications relating to Great Lakes coastal estuaries and wetlands. The visitor center contains natural history exhibits, a freshwater aquarium, weather station, bird viewing area, and art work that depicts the ecology of the estuary. The dormitory, completed in 1987, offers overnight accommodations and cooking facilities for 16 people, while the second dormitory, completed in 2003, houses up to 4 researchers conducting long-term projects (Figure 1.15).

The Division of Natural Areas and Preserves has established a classification system for state nature preserves which reflects their uniqueness, fragility, and extent of use. Old Woman Creek Reserve lands are classified as either scientific or interpretive zones. Scientific zones are the most restricted in use and encompass natural features of the highest quality. They were established for preservation of unique or rare biological communities, plant and animal species, or geological features. The scientific zones are primarily located within and adjacent to the estuary, to the west and south of the Ohio Center for Coastal Wetlands Study. Only scientific research is allowed in these areas. Improvements are not permitted unless necessary for continued preservation of the site. Because of the fragile nature of these areas and the danger of disturbing research in progress, access is by written permit only.

Interpretive zones are comparatively undisturbed or are in the process of returning to their natural or original condition. These areas can withstand moderate use for educational and research purposes. Hiking trails, observation platforms, walkways, and interpretive devices are permitted and have been constructed on a limited basis, while other improvements and facilities are restricted to buffer areas (Figures 1.16 and 1.17). Interpretive zones are located east of the Ohio Center for Coastal Wetlands Study and at the Lake Erie barrier beach (Figure 1.18), as well as two small areas at the far west and south of the Research Reserve.

Figure 1.15. Dormitory at Old Woman Creek SNP & NERR (Charles E. Herdendorf).

Figure 1.16. Observation deck at Old Woman Creek SNP & NERR (Charles E. Herdendorf).

Figure 1.17. Boardwalk at Old Woman Creek SNP & NERR (Charles E. Herdendorf).

Figure 1.18. Barrier beach at Old Woman Creek SNP & NERR (Charles E. Herdendorf).

Berea Sandstone escarpment and abandoned quarry north of Berlin Heights, Ohio (Charles E. Herdendorf).

Chapter 2. Geology

Lake Erie and its coastal watersheds are underlain by middle Paleozoic sedimentary bedrock, composed of limestones, dolomites, shales, and sandstone. These rocks were deposited as sediments under tropical to subtropical conditions ranging from barrier reef habitats to those environments of clastic deposition associated with mountain building episodes related to the tectonic plate collisions taking place to the east. After lithification, uplift following these episodes initiated a long period of erosion that resulted in excavation of a major stream system along the longitudinal axis of the present lake. Late Cenozoic (Pleistocene) continental glaciers further sculptured this valley by overriding the Niagara Escarpment and excavating most deeply in the eastern end of the lake, moderately deep in the central portion, and least deeply over the carbonate bedrock at the western end of the lake. This process formed the distinctive three basins that characterize Lake Erie (Figure 2.1).

During the most recent Wisconsinan glacial advance, 18,000 years before the present (YBP), ice extended as far south as the Ohio River. Thereafter, the ice margin receded in pulses with ground and end moraines deposited across of the present lake; prominent end moraines occur at the junctions of the three basins.

As the ice margin retreated northward a series of proglacial Great Lakes formed across the Lake Erie basin between older end moraines and the ice front. With progressive ice retreat, new and lower outlets were uncovered and new lake stages were formed at successively lower elevations except where minor readvances of the ice temporarily reversed this trend. Massive sand ridges and dunes were deposited along these shores and thick glaciolacustrine sediments were deposited in the offshore regions of each of these lakes. When the glacier retreated from the Niagara Escarpment and the Niagara River outlet was finally available—greatly depressed by the weight of the ice—much of the lake drained and smaller lakes were present only in parts of the eastern and central basins. Isostatic rebound eventually raised the outlet, which brought the lake to near its present level. At this time the present shoreline landforms, including embayments, estuaries, bluffs, dunes, spits, and barrier bars began to form. Human construction works along the shore have greatly modified the natural landforms, often resulting in accelerated erosion rates.

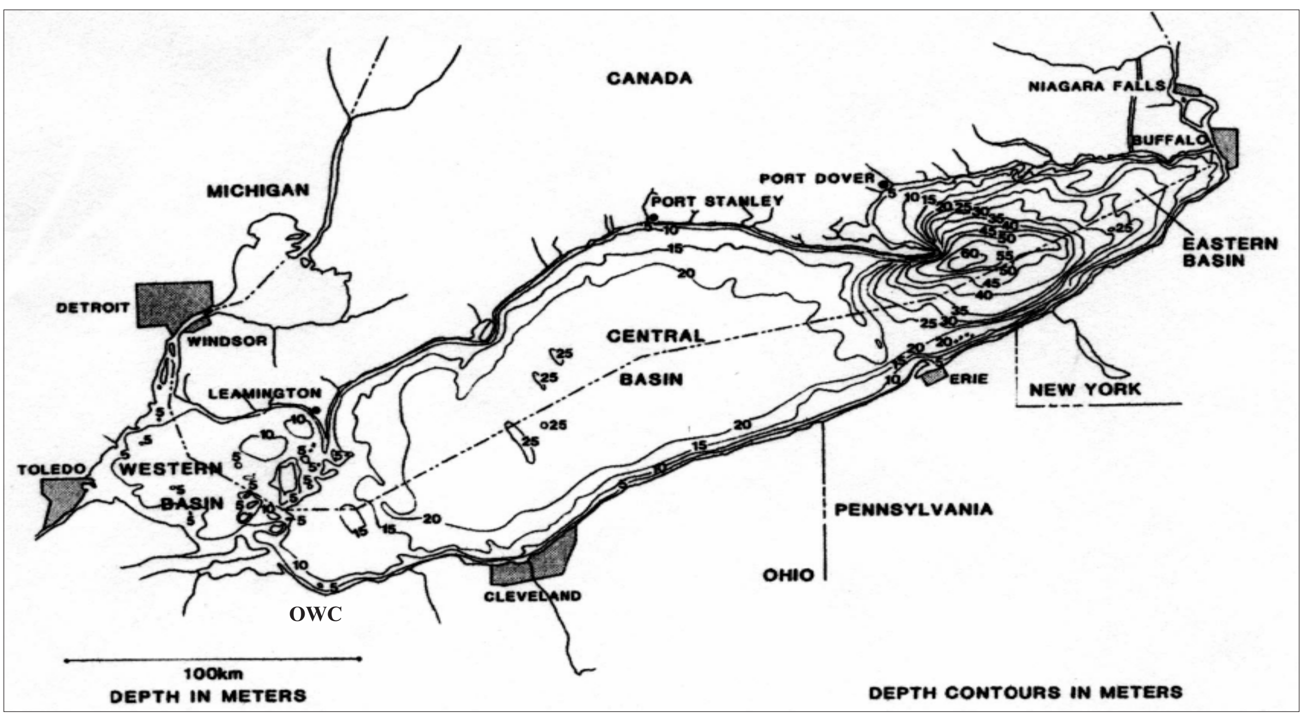


Figure 2.1. Bathymetric map of Lake Erie (from Bolsenga and Herdendorf 1993).

GEOLOGIC HISTORY

PRECAMBRIAN ERA

The earliest record of the geological history of north central Ohio is preserved in the igneous and metamorphic Precambrian rocks of the deep subsurface (see Geological Time Scale p. 13-7). These "basement" rocks are known only from deep well drilling and have been dated at more than 1 billion years old (Coogan 1996). In 1960 the Ohio Fuel Gas Company drilled a 1,340-m-deep well to the Precambrian basement in southeastern Florence Township. Based on southeastern dip of the basement surface at 75 m/km, Old Woman Creek drainage basin is underlain at a depth of about 1,000 m below sea level by metamorphic rocks of the Grenville Province (Owens 1967). These rocks are the remains of a Precambrian mountain range formed by plates that collided 1 to 2 billion YBP. The ancient Grenville Mountains were eroded to an undulating plain in north central Ohio, bounded on the west by a rift valley (similar to the modern Red Sea rift), before the onset of early Paleozoic deposition some 570 million YBP (Coogan 1996).

Precambrian rocks are shallowest in the vicinity of the rift, forming a structural feature known as the Cincinnati-Findlay Arch which extends from southwestern Ohio to western Lake Erie (Figure 2.2). The axis of this arch plunges gently to the north-northeast. As a result, Paleozoic rocks deposited on the Precambrian surface are thinner over the arch and oldest near Cincinnati because of the low relief of Ohio's terrain. Thus, the exposed rocks are progressively younger toward Lake Erie and likewise, younger on the flanks of the arch, east and west of the crest.

The Precambrian rocks underlying Lake Erie are covered by 700 to 1,600 m of Paleozoic sedimentary formations, with the shallowest basement being in the Island Region of western Lake Erie and the deepest near the Ohio and Pennsylvania shore between Cleveland and Erie (Summerson 1962). The oldest Precambrian rocks are primarily crystalline igneous and metamorphic rocks that represent a complex geologic history. This includes the emplacement of a vast, 11-km-thick mass of deep-seated granite and volcanically derived rhyolite, followed by faulting and rifting as molten basalt flowed into rift basins. About 1 to 2 billion YBP, a continental collision of two land masses formed the Grenville Mountains at the eastern end of the lake. Subsequent erosion of these mountains and the transgression of the first Paleozoic seas (570 million YBP) buried the Precambrian surface beneath a thick sequence of sedimentary rocks (Hansen 1996).

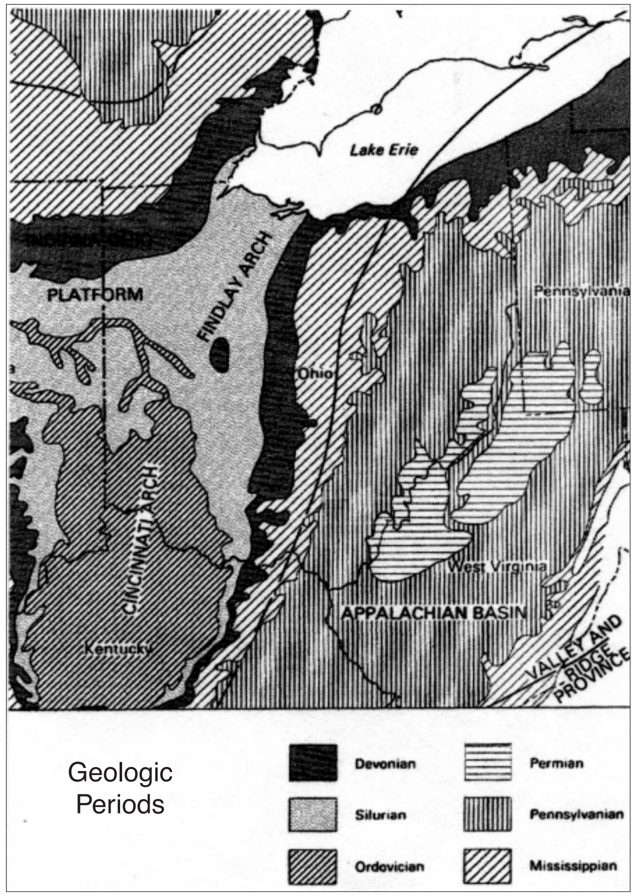


Figure 2.2. Bedrock structure of Ohio (from Feldmann and Hackathorn 1996).

PALEOZOIC ERA

During the Cambrian Period (570 to 505 million YBP) Ohio was part of a broad coastal plain, comparable to the modern Gulf of Mexico coast, that slowly became inundated by the sea. The basement rocks were initially covered by deltaic sands and muds, then by marine carbonates. These sediments were lithified into several hundred meters of sandstones, shales, limestones and dolomites. This period ended with withdrawal of the sea, owing to uplift caused by the collision of the North America Plate with another plate to the east, giving rise to mountain building, known as the Taconic Orogeny.

During the Ordovician Period (505 to 438 million YBP) the ancestral North America continent lay astride the Equator, and Ohio was situated in the Southern Hemisphere. The early part of this period was characterized by subaerial erosion as north central Ohio stood above sea level. During the middle portion of this period the sea again onlapped the continent, resubmerging the eroded surface, and limestones were deposited as carbonate banks, reefs, and lagoon deposits. Late in this period the rocks show a transition from shallow-water carbonates to deep-water limestones and shales as Ohio became part of a rapidly subsiding basin at the culmination of the Taconic Orogeny. Late Ordovician formations are the oldest rocks exposed in Ohio—the noted fossiliferous beds of the Cincinnati area. The period ended when deposition of marine sediments ceased, owing to a drop in sea level which is attributed to glaciation in the Southern Hemisphere (Coogan 1996).

During the Silurian Period (438 to 408 million YBP) sea level rose, flooded the Ordovician surface, and resulted in marine deposition over the crest of the Cincinnati-Findlay Arch. Silurian rocks on the crest and flanks of the arch consist of shallow-water, subtropical, carbonate-bank deposits. Lockport Dolomite, only found in the subsurface rocks of Erie County, was deposited as a reef at this time, and now forms the caprock of Niagara Falls near the outlet for Lake Erie as well as outcrops which are being quarried at the crest of the arch in western Ottawa County, Ohio. The later stages of Silurian deposition reflect a relatively stable, but subsiding, shallow marine environment that periodically experienced lowered sea level and evaporation of the sea water to form thick salt beds (gypsum, anhydrite, and halite) in the Salina Group (Coogan 1996). For many years gypsum was quarried and mined from shallow deposits near Port Clinton, Ohio while rock salt (halite) is being mined from correlative beds more than 500 m beneath Lake Erie at Cleveland and Fairport Harbor, Ohio.

During the Devonian Period (408 to 360 million YBP) another plate collision occurred along the northeastern margin of North America at the start of the period which resulted in uplift, mountain-building, and erosion (Acadian Orogeny). Thus, a major unconformity separates Silurian rocks from Devonian rocks in north central Ohio. During the middle portion of the period, the land was again flooded and sedimentation began in clear seas with the deposition of carbonate sediments that would become the richly fossiliferous Columbus Limestone and other limestones and dolomites. A well drilled in southeastern Florence Township revealed a total thickness of 86 m for subsurface Middle Devonian carbonate rocks (Janssens 1969,1970). Toward the later part of the period, carbonates gave way to the deposition of clay and organic muds that would become the black Ohio Shale which underlies Old Woman Creek estuary. These sediments were deposited in a rapidly subsiding, relatively stagnant offshore marine basin. Overall the shale beds are poorly fossilized, but spectacular fish remains, such as the armored placoderm *Dunkleosteus*, have been found in the Lake Erie bluffs of nearby Lorain County (Newberry 1874). Meanwhile, far to the east, the Appalachian Mountains were being built as a result of another plate collision, forming a landmass known as Laurasia (elements of North America, Europe, and Asia).

During the Mississippian Period (360 to 320 million YBP) erosion of the ancestral Appalachian Mountains formed the Catskill delta, a clastic wedge of sediments deposited on a vast alluvial coastal plain that sloped gently westward (Dott and Batten 1976). In north central Ohio, the dark marine shales of Devonian Period were covered by fluvial, deltaic, and marginal-marine clastic sediments at the western extremity of the wedge. In the Old Woman Creek drainage basin, these depositional environments are represented by the Bedford Shale and Berea Sandstone. The Mississippian rocks form a band of hills and an escarpment 5 to 10 km south of the present Lake Erie shoreline and display characteristics of deltaic and nearshore marine deposition. Another major erosional event ended Mississippian deposition in Ohio and removed any younger Mississippian strata (e.g. Cuyahoga Formation) that may have been deposited on the Berea Sandstone, leaving these beds as the youngest Paleozoic rocks in the watershed.

During the Pennsylvanian Period (320 to 286 million YBP) and the Permian Period (286 to 245 million YBP), Ohio was near the equator and the climate was tropical. Rocks from these periods, exposed only in eastern and southeastern Ohio, indicate an early marginal-marine environment that became progressively more terrestrial, consistent with the ongoing development of the supercontinent of Pangea (Coogan 1996). Weathering has removed any trace of deposits that may have been laid down in Erie and Huron counties during these late Paleozoic periods.

MESOZOIC ERA AND CENOZOIC ERA

During the Triassic, Jurassic, and Cretaceous Periods (245 to 66 million YBP) Ohio experienced uplift, erosion, and weathering. These processes removed all traces of any deposits from the Mesozoic Era, if any were ever present. The same can be said for the Tertiary Period (66 to 2 million YBP) of the Cenozoic Era. Extensive systems of stream valleys dissected the entire surface of Ohio, including the Erie basin, before onset of Pleistocene glaciation. During this 243-million year interval, several hundred meters of rock were likely eroded from Ohio's landscape (Coogan 1996). About 2 million YBP, in response to the cooling of the Earth's climate, continental glaciers moved south from Canada to cover about two-thirds of Ohio at their maximum extent. This event initiated the Quaternary Period, which consists of the Pleistocene Epoch (commonly called the Ice Age) and the Holocene Epoch (last 10,000 years of geologic history). The glacial and postglacial geological events in north central Ohio are discussed in detail in later sections (Glacial Geology and Evolution of Lake Erie).

GEOMORPHOLOGY

The branch of geology that deals with the general configuration of the Earth's surface is known as geomorphology. Specifically, it treats the description, classification, and development of present landforms in relation to underlying geologic structures, as well as the study of geologic changes as recorded in surface features (Bates and Jackson 1980). Several notable geomorphic features occur within the environs of Old Woman Creek. Progressing in a general way from north to south they include: (1) Lake Erie, (2) barrier beach, (3) Old Woman Creek estuary, (4) Star Island, (5) lake plain, (6) abandoned beach ridges, (7) Berea Escarpment, (8) Berlin Heights ravine, (9) till plain, and (10) the valley of Old Woman Creek which traverses the entire area from south to north (Figure 1.6). Each of these features is described in the following section.

LAKE ERIE

Old Woman Creek empties into the central basin of Lake Erie along the Ohio shore at Lat. 41°23'04" N and Long. 82°31'20" W. Lake Erie is one of the largest freshwater lakes in the world, ranking 9th by area and 15th by volume, with a surface area of 25, 657 km^2, maximum depth of 64 m, and a volume of 483 km^3 (Herdendorf 1982). Erie is the southernmost of the North American Great Lakes, geologically the oldest, and by far the shallowest with its entire water mass lying above sea level. Lake Erie is a relatively narrow lake, 388 km long by 92 km wide, with its long axis oriented west southwest-east northeast. This axis parallels the prevailing wind direction which causes the lake to react violently to storms, causing the production of high waves and wide fluctuations in water level.

Based on depth, Lake Erie is divided into three basins: western, central, and eastern (Figure 2.1). The shallow western basin contains a number of bedrock islands and shoals, and represents only 13% of the area and 5% of the volume of Lake Erie. Several passages in the chain of islands at the basin's eastern edge provide water circulation channels.

The central basin is the largest of the three basins, containing 63% of the lake's area and volume. This basin is separated from the western basin by the chain of islands and Point Pelee, Ontario (south of Leamington), and from the eastern basin by a relatively shallow, sand and gravel ridge which crosses the lake in a north-south direction between Erie, Pennsylvania and Long Point, Ontario (south of Port Dover). The central basin has an average depth of 18 m and maximum depth of 26 m. Except for the rising slopes of a bar extending south-southeastward from Point Pelee, the bottom of the central basin is extremely flat. This bar isolates a depression in the bottom between it and the western basin islands that is known as the Sandusky sub-basin.

The eastern basin is relatively deep and bowl-shaped, with a considerable portion of the bottom below 30 m deep and a maximum depth of 64 m (off the tip of Long Point, Ontario). The eastern basin comprises 24% of Lake Erie's area and 32% of its volume (Bolsenga and Herdendorf 1993). The glacially deposited ridge north of Erie, Pennsylvania contains a notch, known as the Pennsylvania channel, which provides a subsurface connection for water circulation between the central and eastern basins.

The varying depths of Lake Erie's three basins are attributed to differential erosion of the underlying bedrock by preglacial streams, glacial scour and deposition, and postglacial lake processes (Carman

1946). For approximately 250 million years prior to glaciation an extensive river system was carved into the bedrock of the region. The Pleistocene glaciers followed these preglacial valleys, scouring them deeper, broadening them, and smoothing their meanders as the ice moved southwestward through the area now occupied by Lake Erie.

As the ice overrode the resistant limestones which now form the brink of Niagara Falls, it dug deeply into the softer Devonian shales of western New York. The ice front was obstructed by the steeply rising Portage Escarpment, composed of resistant sandstones, which lies a few kilometers inland of the present lakeshore between Buffalo, New York and Cleveland, Ohio. Thus the ice was deflected west along an outcrop of soft shale where it scoured these beds to form the deep bottom of the narrow eastern basin. Farther west where the width of the shale belt is greater, glacial erosion resulted in the broader, but shallower, central basin. The western basin owes its islands and shallowness to the tough Devonian and Silurian limestones and dolomites which resisted glacial scour (Herdendorf 1989).

Old Woman Creek flows into the Sandusky sub-basin of the central basin near its southern extremity. The southernmost shore of the Great Lakes system is located on the Sandusky sub-basin at Ceylon Junction (Lat. 41°25’50” N), approximately 2 km east of the mouth of Old Woman Creek estuary. The triangular-shaped Sandusky sub-basin covers approximately 1,350 km^2 or about 8.5% of central Lake Erie. On the west it is bounded by Kelleys Island and Pelee Island, and on the east by the Pelee-Lorain Ridge, which is capped by the Lorain-Vermilion sand and gravel deposit, a ridge crossing the lake between Lorain, Ohio and Pelee Island, Ontario (Herdendorf and Krieger 1989). Over three-quarters of the bottom of the sub-basin has a depth of greater than 11 m, but nowhere does it exceed 15 m. Here the bottom is very flat; slopes of more than 0.5 m/km are nonexistent. Silt- and clay-sized particles make up more than 95% of the bottom material in this flat area. Water depths of 11 m or less are found only on the shoreward rising slopes of the sub-basin and on the ridge (Holcombe et al. 1997).

The Lake Erie nearshore bottom off the mouth of Old Woman Creek estuary slopes lakeward at a rate of 1.2 m /100 m for the first half km (Carter and Guy 1980) and then flattens to 0.12 m/100 m for the next 3.5 km (Holcombe et al. 1997). This yields a depth of approximately 10 m at a distance of 4 km from the shore. Typically, two prominent sandbars, about 0.5 to 0.8 m high, are located within 75 m of the shoreline. Sand deposits extend offshore for a distance of about 400 m where they grade into more silty deposits (Carter and Guy 1980).

BARRIER BEACH

The junction of Old Woman Creek and Lake Erie is marked by a barrier beach which separates the lake from the estuary (Figure 2.3). Based on 1956 aerial

Figure 2.3. Barrier beach at mouth of Old Woman Creek estuary (Charles E. Herdendorf).

photographs, Herdendorf (1963a) reported that a 520-m-long beach extended 275 m to the west and 245 m to the east of the creek mouth; the beach was nearly 60 m wide near its center and tapered to 15 m wide at the ends. Sand dunes, 1-2 m in height, that had formed along the eastern half of the beach were actively being cut by wave action as the bar migrated landward at a rate of about 1 m/yr. Herdendorf (1963a) further observed that the creek mouth was normally barred across, being open only during periods of heavy rainfall and high water levels. However, in recent years the bar has been open for longer periods of time. In 1990, the barrier beach was 418 m long and ranged from 85 to 14 m wide. The particle size of the barrier beach ranges from medium- to coarse-grained sand. The beach is dominantly a quartz sand. Purple and black patches or strands of garnet and magnetite, respectively, are common. The thickness of the sand is greater than 1 m (Carter and Guy 1980) and overlies glacial till that is exposed at lake level east of the beach.

Starting in 1983, daily records on bar openings and closings have been kept. Herdendorf and Hume (1991) reported that during the 8-year period 1983-1990 the inlet was open 59% and closed 41% of the time, but annual percentages ranged from about 30% to 70% for each condition. Using water year 1990 (1 October 1989 to 30 September 1990) as an example, water levels and bar conditions at the mouth show a marked seasonal trend (Figure 2.4). During summer months the estuary mouth is typically barred across. Late in the year, October to December, the water level in the estuary builds up to >1.5 m above LWD at which stage the barrier is usually breached. As the water level in the lake and estuary decline during the winter, the mouth once again bars across. In the spring the water level in the estuary again rises behind the bar until breaching occurs. However, this generalized seasonal pattern is often subject to disruption by short-term meteorological conditions. The rapid water rise in the estuary in the latter part of the year (Figure 2.5) appears to be the result of the damming-effect of the barrier bar; neither precipitation nor runoff (Figures 2.6 and 2.7) are sufficient to totally account for the nearly 500,000-m^3 increase in the water stored in the estuary prior to the fall breach. Overtopping of the bar by lake waves is also believed to supply a sizable quantity of water to the estuary, particularly during northeast storms (Herdendorf and Hume 1991). When the bar breaches a classical “ebb tide delta” is built into Lake Erie at the mouth of the inlet. Sand from the barrier is flushed into the lake through a narrow discharge channel and deposited when velocities of the exiting water drop below the transport threshold, about 2 cm/s for medium-grained sand (Herdendorf 1975).

OLD WOMAN CREEK ESTUARY

The estuary comprises the lower 3 km of the Old Woman Creek. Examination of the bathymetric map prepared by Herdendorf and Hume (1991) reveals the estuary to be a broad, shallow basin that has been modified by man-made structures which tend to constrict and segment the original basin (Figure 2.8). Construction of the U.S. Route 6 bridge about 120 m south of Lake Erie and the Conrail causeway and bridge another 1.2 km to the south has resulted in estuary’s segmentation into three sections: (1) lake lagoon, (2) main basin, and (3) south basin. Figure 2.8 also shows that an incised channel runs the entire length of the estuary and carries discharge waters directly into Lake Erie. When the water level in the estuary is standing at the mean level of Lake Erie (elev. 174.1 m IGLD 1985 or + 0.6 m LWD) the average depth of the estuary is only 0.2 m. At typical water levels (elev. 174.5 m or +1.0 m LWD) the estuary has an area of 520,000 m^2, a volume of 190,000 m^3, and a mean depth of 0.4 m. Other morphometric relationships for the estuary are presented in Table 2.1. The lake lagoon, main basin, and south basin, respectively, comprise 4%, 82%, and 14% of the total estuary area.

The lake lagoon is a small, elongated basin (east-west direction) that lies between U.S. Route 6 and the barrier beach that separates the estuary from Lake Erie (Figure 2.9). The outlet channel presently runs along the west side of the sub-basin. The beach area east of the outlet channel is known as Oberlin Beach. Aerial photographs taken over the past 60 years show that this lagoon was at one time more circular, when the barrier beach forming its north side was more than 100 m farther lakeward. Recession of the shore, primarily the result of northeast storms, has taken place as waves overtopped the barrier bar and washed beach sand into the lagoon. Since 1937, the channel through the barrier bar has migrated from its present position to 200 m farther east and back again. The deepest portion of the lagoon occurs in scour channel near the U.S. Route 6 bridge (-1.5 m LWD). From the bridge to the lake the depth of the channel averages about -0.3 m LWD.

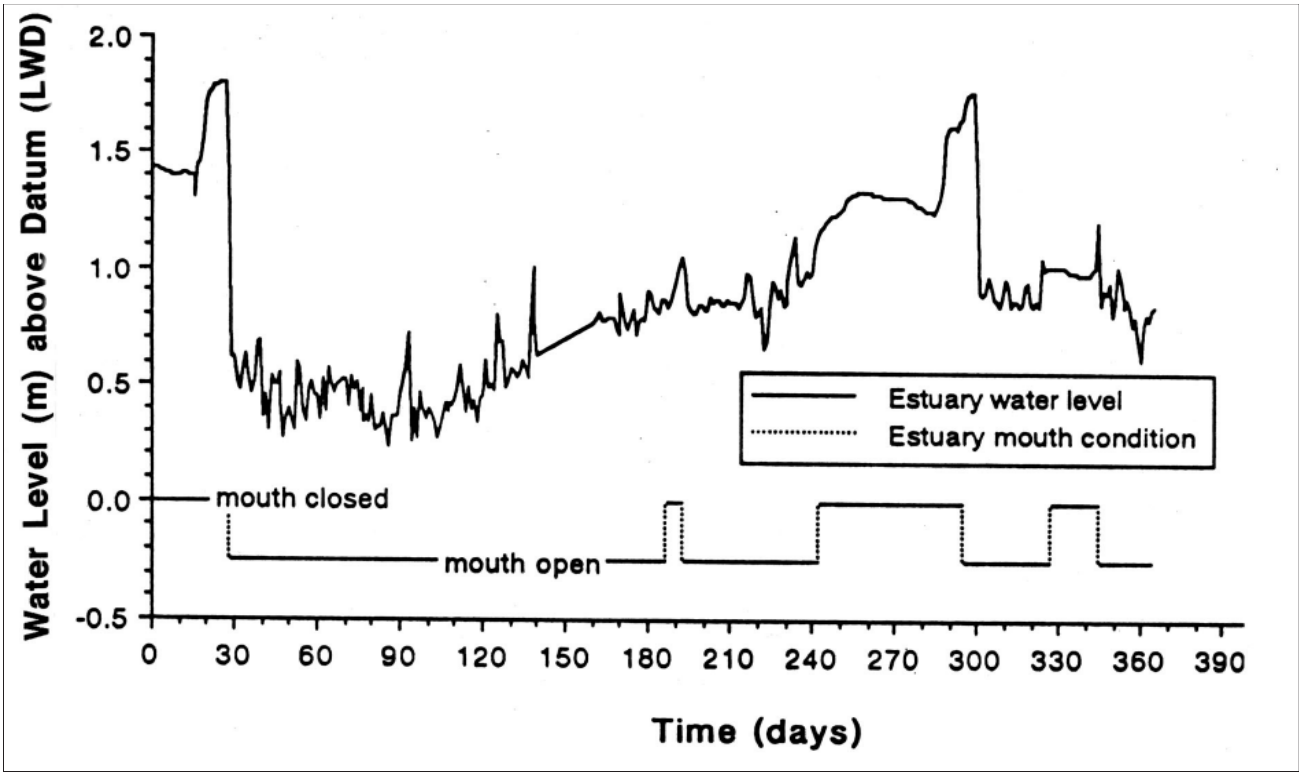


Figure 2.4. Water levels in Old Woman Creek estuary showing open/closed condition of inlet for water year 1990 (1 October 1989 to 30 September 1990).

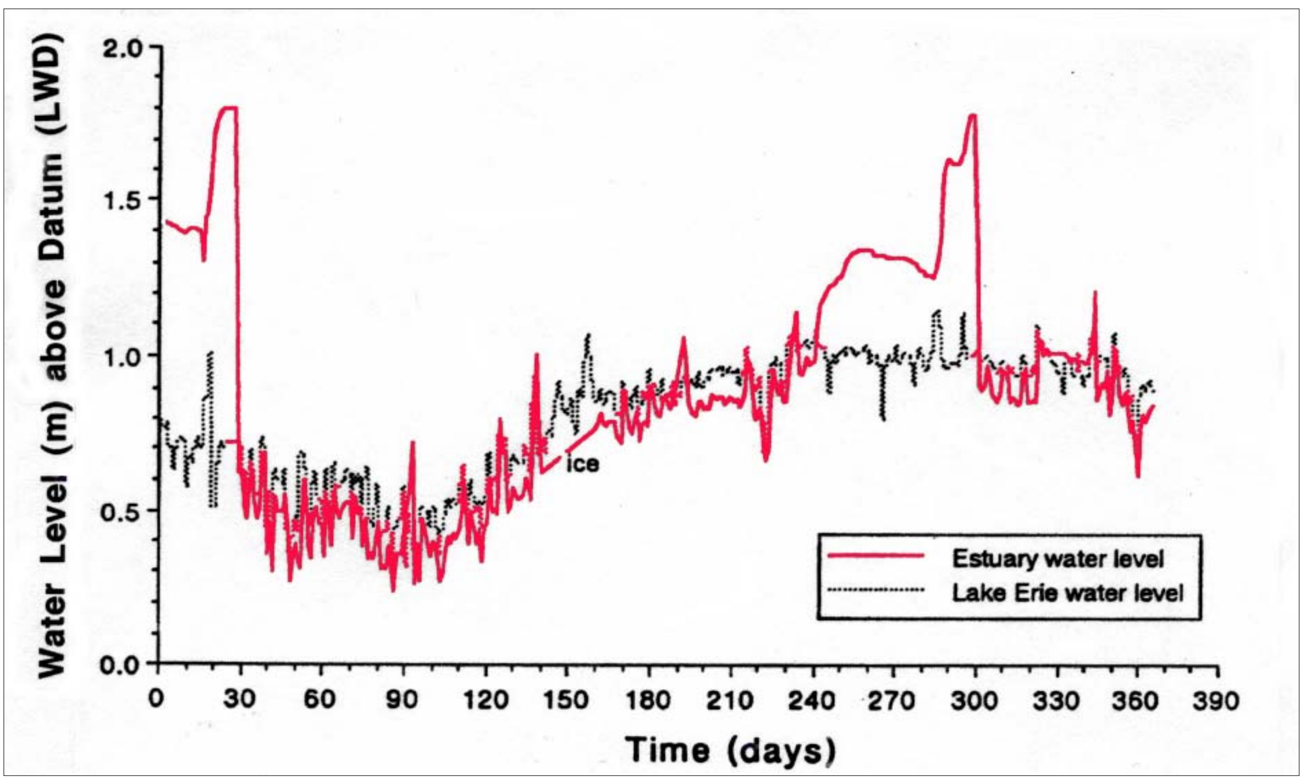


Figure 2.5. Water levels in Old Woman Creek estuary plotted versus Lake Erie water levels for water year 1990 (1 October 1989 to 30 September 1990).

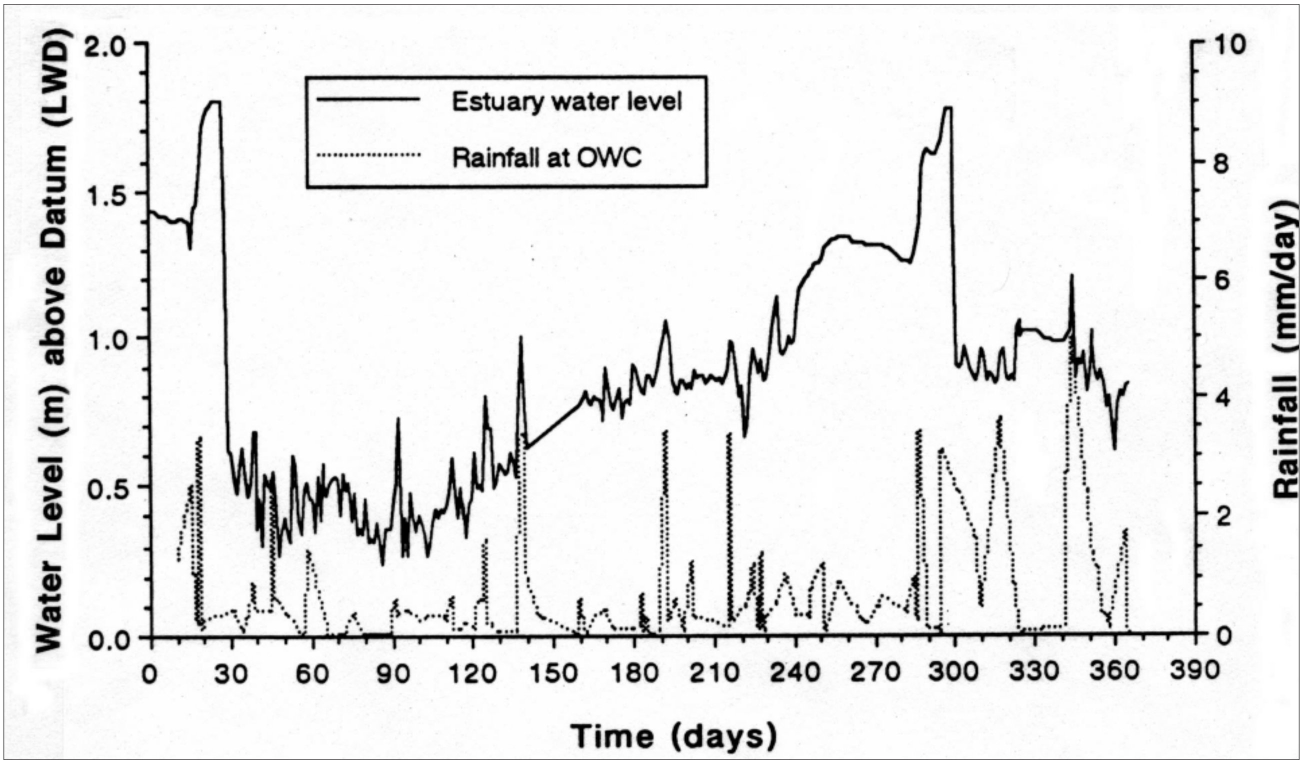


Figure 2.6. Water levels in Old Woman Creek estuary plotted versus rainfall for water year 1990 (1 October 1989 to 30 September 1990).

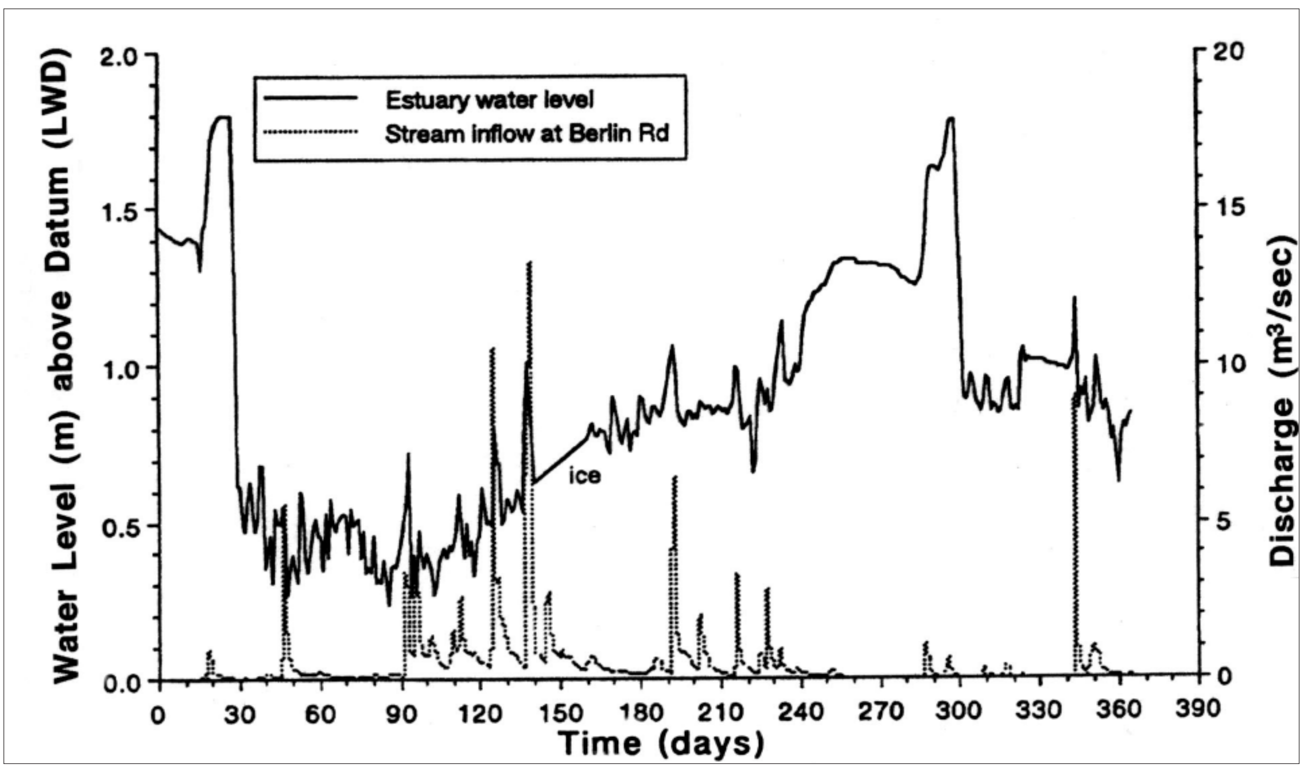


Figure 2.7. Water levels in Old Woman Creek estuary plotted versus stream inflow for water year 1990 (1 October 1989 to 30 September 1990).

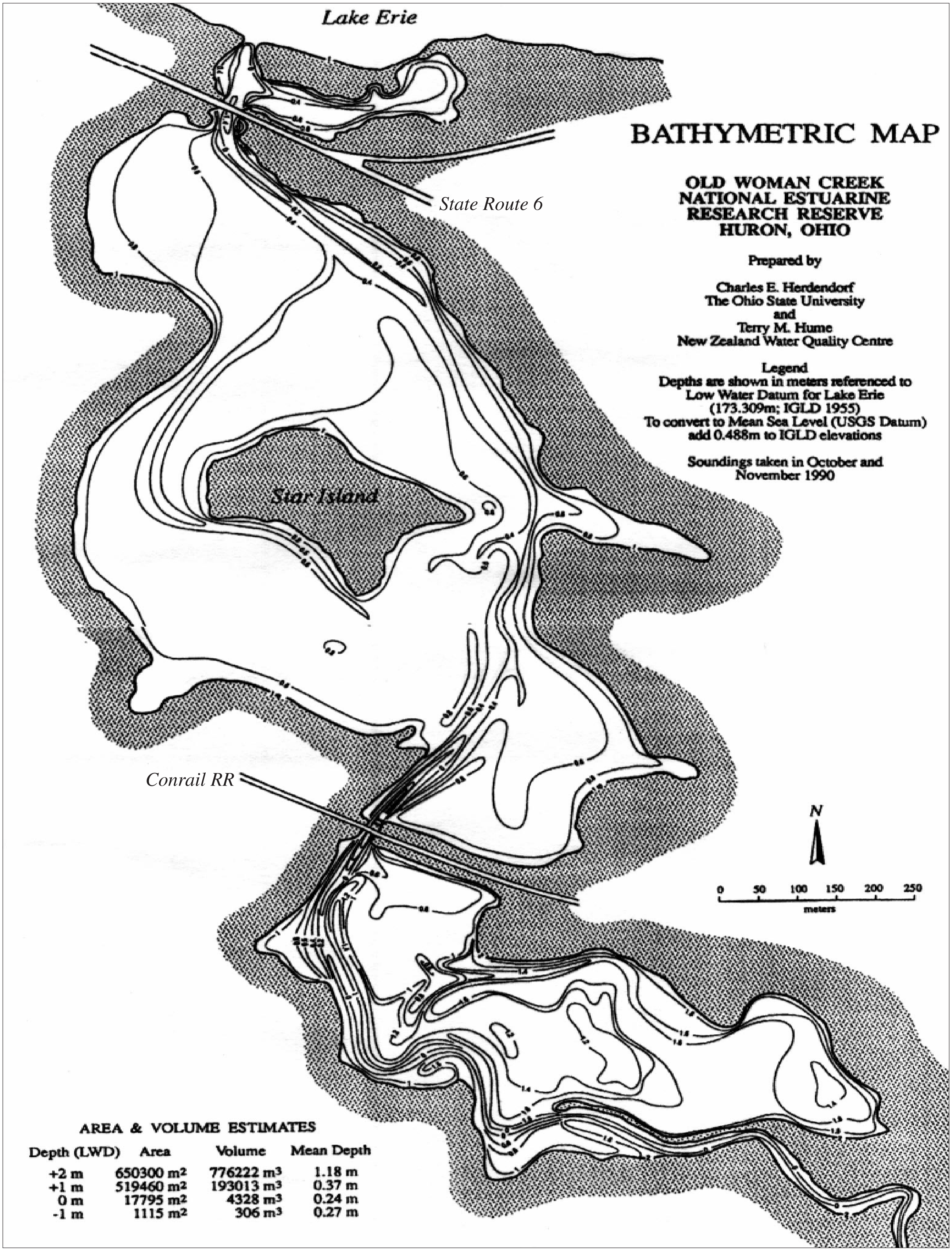


Figure 2.8. Bathymetric map of Old Woman Creek estuary (from Herdendorf and Hume 1991).

The main basin of the estuary is lacustrine-like and consists of a broad shallow basin (Figure 2.10) that is cut by a narrow channel along its eastern margin (Figure 2.11) and a secondary channel that splits off the main channel at the southern end of the basin and follows a course to the west. The channels are shallow, generally with bottom elevations a few tenths of a meter above LWD and only a few tenths of a meter below the surrounding bottom of the estuary (Herdendorf and Hume 1991). Star Island (Figure 2.12) is located between these channels near the center of this basin. A natural levee, that is more persistent in the south basin, extends into the main basin as far north as Star Island. The main basin is surrounded by relatively steep escarpments on all sides, including Star Island. Into the escarpments, on both sides but particularly the east side, intermittent tributaries have cut several deeply entrenched, but shallow, coves. The majority of the basin has a floor elevation ranging from +0.4 to +0.6 m LWD. This produces a depth that is particularly conducive to growth of dense beds of *Nelumbo lutea* (American water lotus). The highway and railroad constrictions at the north and south ends, respectively, of the basin are the deepest portions of the entire estuary. The channel at the U.S. Route 6 bridge is 18 m wide and has a maximum depth of -1.7 m LWD; whereas the channel at the Conrail bridge is 13 m wide and has a maximum depth of -0.9 m LWD.

The south basin (Figure 2.13) of the estuary is more riverine-like and is comprised of a narrow channel that extends south from the Conrail bridge to the vicinity of the Darrow Road bridge. The channel is relatively deep (maximum -0.2 to -0.7 m LWD) and flanked by natural levees along most of its course. A number of small, tributary-mouth lagoons are present along the estuary's west bank and an extensive lagoon and swamp forest is found along the east side of the estuary. This lagoon was a continuation of the main basin of the estuary, but it is now terminated on the north by the railroad causeway. The lagoon occupies an area with bottom elevations between +0.6 to +1.0 m LWD, whereas the swamp forest occurs where the bottom elevation ranges from about +1.0 to +2.0 m LWD. The deepest depths in the south basin occur in a narrow scour channel under the Conrail bridge (-0.7 m LWD).

TABLE 2.1. MORPHOMETRIC DATA FOR OLD WOMAN CREEK ESTUARY

Parameter	Dimension*
Maximum depth (z_m)	2.68 m
South basin	1.67 m
Main basin	2.68 m
Lake lagoon	2.46 m
Mean depth ($\bar{z}$)	0.37 m
Relative depth (z_r)	0.33%
Maximum length (l)	2000 m
Max. effective length (l_e)	1125 m
Maximum breadth (b)	670 m
Mean breadth ($\bar{b}$)	260 m
Closure index (ci)	0.02
Area (a)	519,460 m^2
Volume (v)	193,013 m^3
Shore length (l)	9616 m
Insulosity (i_n) [Star Is.]	7.64%
Shoreline development (d_l)	3.75
Volume development (d_v)	0.41
Orientation of main axis	335°
Slope of basin	
1.8 to 2.0 m	8.54%
1.6 to 1.8 m	1.89%
1.4 to 1.6 m	3.33%
1.2 to 1.4 m	2.86%
1.0 to 1.2 m	11.30%
0.8 to 1.0 m	1.79%
0.6 to 0.8 m	0.79%
0.4 to 0.6 m	0.92%
0.2 to 0.4 m	4.95%
0.0 to 0.2 m	12.14%
-0.2 to 0.0 m	5.98%
-0.4 to -0.2 m	8.75%
Mean slope (s)	1.85%
Length of contour lines (l_z)	
2.0 m	9,923 m
1.8	10,162 m
1.6	11,451 m
1.4	10,972 m
1.2	10,090 m
1.0	9,616 m
0.8	9,250 m
0.6	8,298 m
0.4	7,124 m
0.2	4,258 m
0.0	3,402 m
-0.2	2,892 m
-0.4	1,918 m
-0.6	505 m
-0.8	381 m
-1.0	235 m
-1.2	185 m
-1.4	133 m
-1.6	30 m

* based on water level of +1.0 m LWD (= 174.49 m or 572.48 ft IGLD, 1985)

Figure 2.9. Lagoon at mouth of Old Woman Creek estuary (Charles E. Herdendorf).

Figure 2.10. Main basin of Old Woman Creek estuary from southern extremity (Charles E. Herdendorf).

Figure 2.11. Channel along eastern side of main estuary basin; upstream view from observation deck (Charles E. Herdendorf).

Star Island

The valley of Old Woman Creek within the estuary has two distinct channels between the Conrail and the U.S. Route 6 bridges resulting from a bifurcation about 150 m north of the railroad. This bifurcation has preserved an isolated remnant of the lake plain known as Star Island around which the creek flowed to the east and to the west at various times (Buchanan 1982). The roughly star-shaped island now lies near the center of the estuary (Figure 2.14). The distance between its east and west points is about 450 m and 275 m between it north and south points. The sides of the island rise rather steeply to a flat top about 9 m above the mean water level of the estuary. The entire island comprises an area of 45,000 m^2 (4.5 hectares) and its flat top has an area of nearly 1 hectare. Star Island is the only island in the estuary with an elevation significantly above that of the water surface.

The erosional, rather than depositional, origin of Star Island has been inferred from the accordant height of the island with the surrounding uplands and the from the largely undisturbed lake plain sediments on the island's surface (Buchanan 1982). The soil types of the island, Sisson silt loam and Tuscola loamy fine

*Figure 2.12. Prolific stands of common reed (*Phragmites australis*) flanking Star Island (David M. Klarer).*

Figure 2.13. Southern basin of estuary and surrounding swamp forest (Charles E. Herdendorf).

sand, also match those of the surrounding upland areas of the lake plain (Redmond et al. 1971). These soils formed in stratified limy silt and very fine sand that was deposited on the bottom of glacial lakes with levels higher than modern Lake Erie.

The majority of the erosion around Star Island is believed to have occurred during a period of rejuvenation of Old Woman Creek downcutting following glacial retreat (Buchanan 1982). The preservation of the island remnant appears to be the result of entrenched meanders of the creek bed at that time. The arcuate gorges around the periphery of the island, forming the points of the star shape, suggest that the active channel of the creek has eroded into the island from various directions at various times. The relative steepness of these erosional scars is most likely inversely proportional to the age of the channel erosion adjacent to the slope, which enabled Buchanan (1982) to develop a chronology for the erosional history of the island (Figure 2.15). Thus, the gently sloping north and northwest sides of the island have the oldest shorelines and represent the oldest channels while the steeply sloping southwest side represents the youngest.

LAKE PLAIN

A band of relatively flat land paralleling the Lake Erie shore and extending inland approximately 5 km on the east side of the Old Woman Creek and 10 km inland on the west side is known as the lake plain (Figure 2.16). It is a nearly level to gently undulating plain broken only by the steep-sided valleys of the two main branches of the creek and several abandoned beach ridges. The surface topography of the lake plain slopes lakeward at an average of 2 m/km or 0.2% (Buchanan 1982). The lake plain is terminated to the south by the steeply rising Berea Escarpment.

The plain was covered by the waters of several glacial lakes that once occupied the Lake Erie basin. Conspicuous sand and gravel ridges, 3 to 6 m above the plain and 30 to 60 m wide, mark the former shorelines of these lakes (Herdendorf 1963b). The sediments deposited in these lakes form the surface material of the plain. These glaciolacustrine deposits consist largely of interlaminated clay, silt, and fine sand that overlie glacial till (Carter and Guy 1980). Generally, the soils of the lake plain mirror the underlying glaciolacustrine parent material. Lenawee-Del Ray association soils have formed on deposits rich

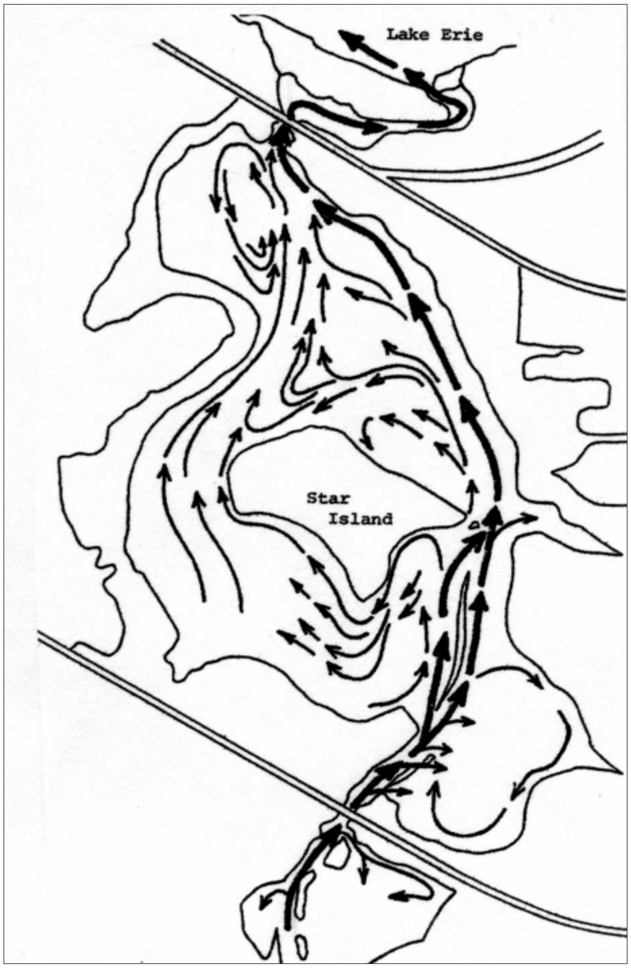


Figure 2.14. Dominant water circulation patterns in Old Woman Creek estuary (from Buchanan 1982).

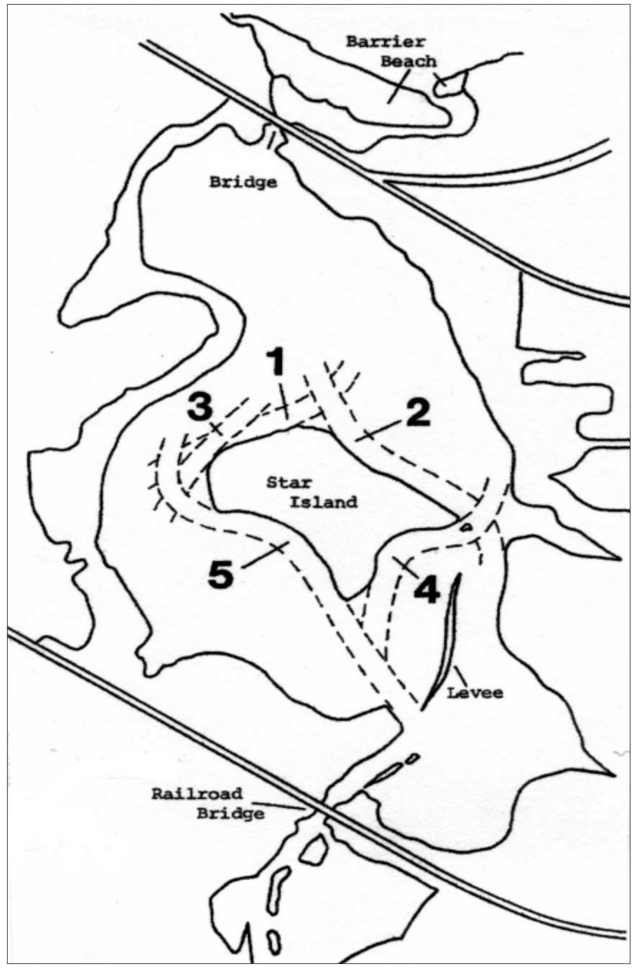


Figure 2.15. Channel migration chronology at Star Island in Old Woman Creek estuary (from Buchanan 1982).

in clay and silt; whereas deposits containing more silt and fine sand have produced soils of the Kibbie-Tuscola-Colwood and the Sisson-Tuscola associations (Redmond et al. 1971).

ABANDONED BEACH RIDGES

Several stages of six glacial lakes covered the lake plain with water depths 15 to 70 m higher than modern Lake Erie, the most prominent of these include Lakes Maumee, Arkona, Whittlesey, Wayne, Warren, and Lundy (Carney 1911). The abandoned, sandy beaches of these lakes form a series of more or less parallel ridges trending northeast-southwest at the southern edge of the lake plain (Figure 2.17). The topographic profile of this part of the watershed is that of successively lower lake-plain terraces with a several-meter-high beach ridge and sand dunes at their southern terminus (Herdendorf 1963b). The major ridges (Maumee, Whittlesey, and Warren) are confined to a 2-km-wide belt because of the rather rapid rise in the land surface at the southern edge of the lake plain as the plain merges with the Berea Escarpment (Figure 2.18). Where the ancient shorelines coincided with outcrops of Berea Sandstone, wave-cut, headland features such as vertical cliffs, overhangs, arches, and caves were produced (Figures 2.19 and 2.20). The reader is referred to the section of this Chapter titled Evolution of Lake Erie: Glacial and Postglacial Lakes for more detailed information on glacial lakes associated with the abandoned beach ridges.

Studies of concentrations of erratic boulders in Erie and Huron counties by Campbell (1955) showed that the highest numbers are associated with the ancient beach ridges. The large accumulations are thought to be a result of severe shore erosion at the base of the ridges or possible ice rafting of rock fragments from

Figure 2.16. Lake plain south of Old Woman Creek estuary (Charles E. Herdendorf).

Figure 2.17. Abandoned beach ridge and dune of glacial Lake Maumee at Berlinville, Ohio (Charles E. Herdendorf).

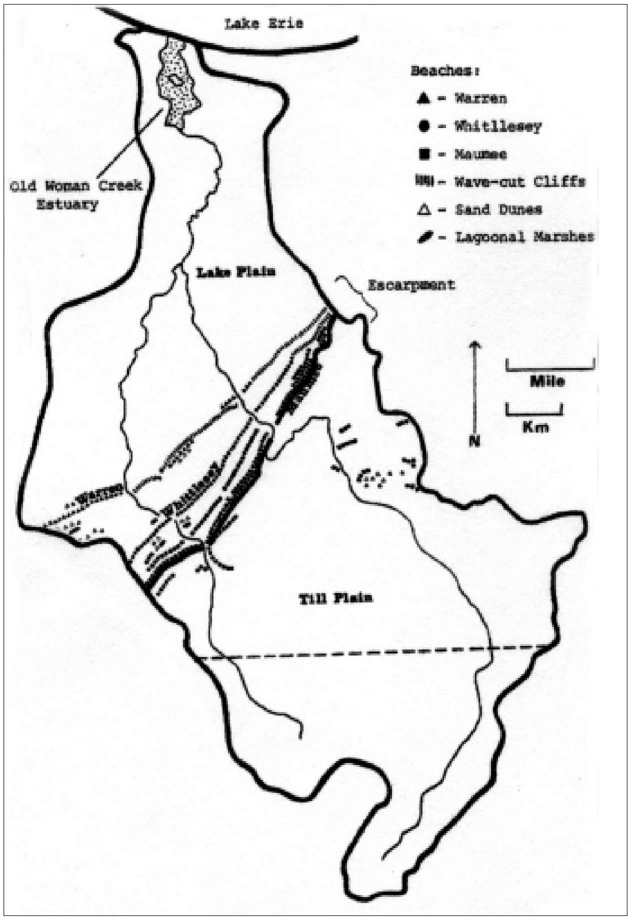


Figure 2.18. Abandoned beach ridges and wave-cut cliffs in Old Woman Creek watershed; trends of ridges are aligned with the Huron River embayment to the east of the watershed (from Buchanan 1982).

glaciers located to north. Deposits of bog iron ore and peat occur locally in association with the former marshy areas or lagoons between the beach ridges. The reddish-brown Vaughnsville loam has formed on the bog iron deposits. This soil is best developed north of Mason Road in Vermilion Township (10 km northeast of Berlin Heights) and south of Hill Road in Berlin Township (2 km southeast of Berlin Heights). The soils that developed on the gently sloping, sandy beach ridges are in the Arkport-Galen and Mahoning-Bogart-Haskins-Jimtown associations (Redmond et al. 1971).

BEREA ESCARPMENT

The Berea Escarpment is the erosional surface expression of the northern edge of the Berea Sandstone outcrop (Figure 2.21). Berea Sandstone is the most resistant bedrock formation exposed in the watershed. Erosion has left it standing proud, well above the surrounding shale beds. The escarpment occurs in a nearly 2-km-wide band that extends in a northeast-southwest direction across the midsection of the watershed. Impressive rock gorges have been cut through the escarpment by the east and west branches of Old Woman Creek. The surface topography of the escarpment slopes lakeward at an average of 17.5 m/km or 1.75% (Buchanan 1982). The local relief of the escarpment near Berlin Heights approaches 60 m.

The base of the escarpment lies at an elevation of about 201 m (660 ft) and rises to a maximum elevation of 259 m (851 ft) northeast of Berlin Heights. The steepness of the escarpment's north slope is governed by the relative erosion resistance of the underlying rocks. From an elevation of 201 to 213 m (660 to 700 ft) the slope is steep (1 m vertical in 7 m horizontal) in response to the hard, black Ohio Shale. From 213 to 219 m (700 to 720 ft) the escarpment is more terrace-like (1 m vertical in 20 m horizontal) under the influence of the soft, gray Bedford Shale. From 219 to 259 m (720 to 850 ft) the slope once again becomes steeper (1 m vertical in 4 m horizontal) where underlain by resistant Berea Sandstone which forms the caprock for the escarpment.

Soils of the escarpment are within the Mahoning-Bogart-Haskins-Jimtown association, especially those of the Berk series (Redmond et al. 1971). Typically these soils are acid, light-colored, well-drained, and underlain by weathered sandstone from which they have formed.

BERLIN HEIGHTS RAVINE

The ravine of Old Woman Creek at Berlin Heights exhibits the maximum relief in the watershed. From the floor of the creek to the top of the gorge, the vertical height of the walls reach a maximum of 27 m and the width ranges from 100 m to nearly 200 m. The ravine begins at the foot of the Berea Escarpment, near the place where the Ohio Turnpike crosses the east branch of Old Woman Creek, and extends south (upstream) for about 2 km to Ohio Route 61. The creek bed drops 35 m in a series of riffles as it passes through the ravine. Impressive exposures of Berea Sandstone can be seen in the upper walls of the ravine and Ohio Shale crops out in the bed of the stream (Figure 2.22). A similar but less spectacular gorge occurs on the west branch of Old Woman Creek where the stream cuts through the Berea Escarpment in the vicinity of Berlinville.

Figure 2.19. Wave-cut features in Berea Sandstone 30 km east of Berlin Heights, Ohio (Charles E. Herdendorf).

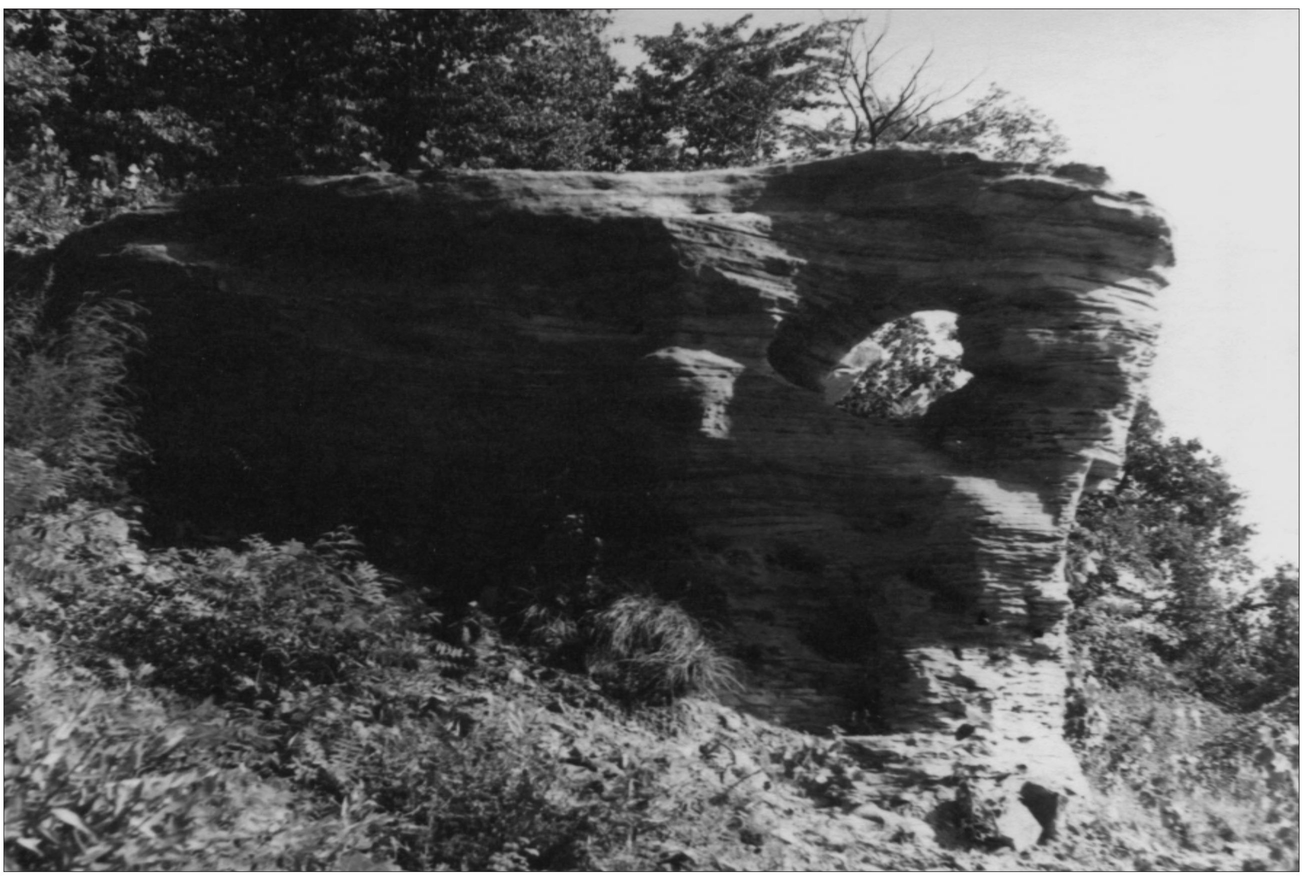


Figure 2.20. Berea Sandstone cliff (at same location as Figure 2.19) sculptured by wave action during glacial Lakes Maumee and Whittlesey (Charles E. Herdendorf).

Figure 2.21. Wave-etched sandstone cliff of glacial Lake Maumee near crest of Berea escarpment at Berlin Heights, Ohio (Charles E. Herdendorf).

Figure 2.22. Downstream view from floor of Berlin Heights ravine (Charles E. Herdendorf).

Till Plain

The southern half of the watershed consists of glacial till plain (Figure 2.23). This plain lies southeast of the highest Lake Maumee beach ridge which generally coincides with the lakeward slope of the Berea Escarpment. The surface topography of the till plain slopes lakeward at an average of 5 m/km or 0.5% (Buchanan 1982). The till plain is a large expanse of glacially deposited ground moraine that extends beyond the limits of the watershed to the Defiance end moraine in southern Huron County (15 km south of Berlin Heights). The till plain is more rolling than the lake plain and represents an area over which the ice edge advanced and retreated rapidly without halting (Herdendorf 1963b). The plain is only moderately dissected by the tributaries of Old Woman Creek and lake plain about 2 km south of the estuary.

The channel of Old Woman Creek as it passes through the till plain drops from an elevation of 270 to 229 m (885 to 750 ft). The average gradient for this 12-km section is 3.4 m/km or 0.34 %. The stream gradient is less steep than that of the surface topography of the till plain because of the effects of channel cutting into the till surface. The heights of valley walls in this section range from nil at the headwaters to 8 m near Berlinville. The dendritic stream pattern of Old Woman Creek in the till plain is classified as being in a "late youthful" development stage (Buchanan 1982).

At an elevation of 229 m (750 ft) significant exposures of bedrock appear in the creek valley and continue to an elevation of 186 m (610 ft) as the creek traverses the 3.7 km of the Berea Escarpment (Figure 2.24). The stream gradient for this section is 11 m/km or 1.1%. The erosion of deep gorges and ravines in the bedrock of the escarpment has also reduced the stream gradient below the gradient of the surface topography. The gorges in this section have valley walls up to 27 m high. The dendritic stream pattern of Old Woman Creek shows some rectangular influences within the rock exposures of the escarpment and is classified as being in a "youthful" development stage (Buchanan 1982).

Below an elevation of 186 m (610 ft) and on to its mouth, a distance of 8.7 km, Old Woman Creek traverses the lake plain. The stream gradient in this section is only 1.3 m/km or 0.13%, although the lacustrine sediments in the section are easily eroded yielding some deep channels. The wide floodplain, U-shaped valley, and meandering pattern of the creek all reflect a "mature" stage of stream development (Buchanan 1982). The heights of valley walls in this section range from 8 to 12 m.

BEDROCK GEOLOGY

The bedrock exposed in the Lake Erie region was formed during the middle portion of the Paleozoic Era, that span of time from 300 to 500 million YBP. Geologists have named 62 bedrock formations that crop out in the states and province which surround Lake Erie (Bolsenga and Herdendorf 1993). The varying depths of Lake Erie's three basins are attributed to differential erosion of the bedrock by preglacial streams, glaciers, and postglacial lake processes (Carman 1946). This erosion is largely in response to the hardness and structure of the underlying formations. Lake Ontario is separated from Lake Erie by resistant

Figure 2.23. Rolling glacial till plain southeast of Berlin Heights, Ohio (Charles E. Herdendorf).

Figure 2.24. Tributary stream to Old Woman Creek crossing Berea escarpment north of Berlin Heights, Ohio (Charles E. Herdendorf).

Silurian limestones and dolomites of the Niagara Escarpment. However, the central and eastern basins of Lake Erie are underlain by nonresistant shale, shaly limestone, and shaly sandstone of Late Devonian Age, which dip gently to the southeast. Inland along the south shore, eastward from Cleveland, the Portage Escarpment, composed largely of Mississippian sandstone, rises 100 m above the level of the lake and forms the northwest front of the Appalachian Plateau.

An outcrop belt of Devonian shales swings inland between Cleveland and Sandusky and continues southward through central Ohio in response to the structural pattern of the bedrock. The shallow western basin is underlain by Silurian and Devonian limestones and dolomites on the northward plunging end of the Findlay Arch of the Cincinnati Anticline. Glacial erosion had relatively slight effects on these resistant rocks other than to form impressive grooves such as those found on Kelleys Island and the Bass Islands. The glacial scour was probably controlled by the preglacial stream valleys, resulting in the shallow basin and the island chain.

The bedrock in the islands area of western Lake Erie is sedimentary in origin and was deposited as lime muds in shallow, warm Silurian and Devonian seas, which covered the region from 410 to 375 million YBP. The existence of evaporite beds such as halite (rock salt) and gypsum indicate that several isolated basins occurred at this time. Enclosed by barrier reefs, the waters were repeatedly evaporated to form the massive salt deposits. Halite deposits in the vicinity of Cleveland are currently being mined 700 m below the lake bottom. The warm, clear conditions of the Devonian sea can be inferred from the abundant fossil corals and other invertebrates found in the rocks on Kelleys and Johnson Islands.

While the shallow Devonian sea occupied the islands area, the Appalachian Mountains were being built to the east. Investigations of plate tectonics (Bird and Dewey 1970; Kennett 1982) indicate that the collision of the northwest coast of Africa and that of eastern North America (Appalachian Orogeny) caused sediments to be folded into a formidable mountain chain. Erosion of these newly formed mountains resulted in the deposition of shales and sandstones which cover the limestones in central and eastern Lake Erie.

Much of the south shore of central Lake Erie is a wave-cut bluff composed of hard, black shale (Ohio Formation) of the Late Devonian Age. Bluff heights are 20 to 24 m east of Cleveland where shale and siltstone outcrop near lake level and only form the basal bluff structure when present. Bedrock, however, does form much of the lake bottom to 1.5 km offshore intermittently from Vermilion, Ohio to Erie, Pennsylvania.

Following the deposition of the black Devonian shales, during the Mississippian and Pennsylvanian periods, new deltas were built from the north into the shallow mid-continent sea where Lake Erie is now located. Sandstones and shales were deposited inland from what is now the lake's south shore to form the red beds of the Bedford Shale, the ridge-forming strata of the Berea Sandstone and the "pudding stone" quartz pebbles of the Sharon Conglomerate. Each of these formations has been quarried for building materials. When deeply buried beneath a caprock, the sandy beds of these formations are excellent aquifers and reserves for gas and oil.

Preglacial Topography

A long period of erosion ensued following the deposition of the Upper Paleozoic rock and little is known of the geologic processes for over 250 million years. Here, the geologic record stops until the glacial deposits of the Late Cenozoic. Deep river valleys were cut into the bedrock surface during this interval, including a major drainage system in the vicinity of Old Woman Creek (Herdendorf 1963b). Figure 2.25 illustrates the magnitude of this ancient valley which is now filled with glacial drift.

Edwin Lincoln Moseley, Sandusky High School science teacher, announced in the 22 July 1909 edition of the *Erie County Reporter* that he had traced an ancient rock valley from Willard, in southwestern Huron County, through Norwalk and Milan to the shore of Lake Erie at the mouth of Old Woman Creek. He discovered the ancient valley by inspecting water well records which showed it to be over 2 km wide, filled with over 50 m of glacial drift, and probably formed by a larger river than any now flowing in this part of the state. The deepest wells that did not penetrate rock were found between Milan, Ohio and Lake Erie. Moseley concluded that when the ice which formed a thick covering over the region in the glacial period

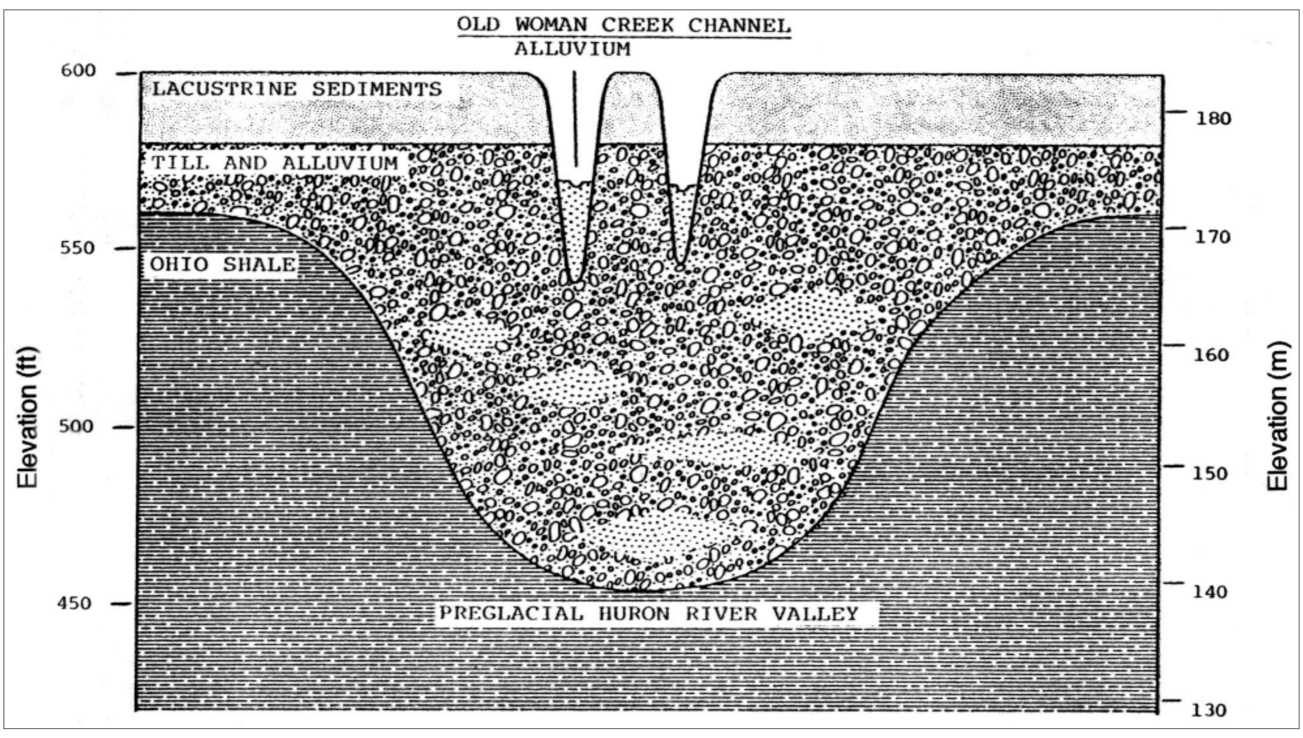


Figure 2.25. Cross-section of buried preglacial Huron River valley at mouth of Old Woman Creek; valley width 4 km (from Herdendorf 1963b, Buchanan 1982).

finally melted away it left behind great quantities of clay and gravel which filled the valley so completely that its existence was not suspected (Frohman 1973).

EXPOSED BEDROCK FORMATIONS

Paleozoic rocks, mainly shales and sandstones, of the Late Devonian and Early Mississippian Periods are exposed within the Old Woman Creek drainage basin (Figures 2.26 and 2.27). Subsurface formations, mainly limestones and dolomites, of the Silurian, Late Devonian, and Middle Devonian Periods underlie these rocks, but are themselves exposed in the western portions of Erie County, Ohio. The following section provides a lithologic description of each bedrock formation exposed in Erie County. These descriptions are modified from Herdendorf (1963b,1966,1967).

Early Mississippian Period

Berea Sandstone. This sandstone formation is gray, blue, or buff, medium- to fine-grained, clay-bonded, thin-layered to massive, cross-bedded and ripple-marked. Principal grains are clastic subangular to subrounded quartz showing secondary enlargement; with lesser amounts of microcline, orthoclase, plagioclase, muscovite, leucoxene, zircon, tourmaline, calcite, chlorite aggregates, and rims of siderite; bonding material chert, sedimentary rock fragments, and clay. Formation is divided into three parts: (1) lower channel sandstone, present only as fills in erosion valleys in the Bedford and Cleveland Shales (Figure 2.28), characterized by steep walls, rounded basal profiles, and meander patterns; (2) middle massive sandstone, strongly crossbedded and containing flow rolls (Figure 2.29); (3) upper thinly bedded marine sandstone, 6 to 10 m thick, with upper surface of beds showing distinct oscillation-type ripple marks (Figure 2.30). Fossils are rare. Formation is highly resistant, forming ridges and hills in the southeastern part of the county, and influencing orientation of Pleistocene beach ridges and lake bluffs. Northern edge of outcrop, particularly along Chappel Creek in northwestern Florence Township exhibits complex and possibly glacially related folding, faulting, and overturning. Since mid-1800s at least 10 sites have been worked for dimension, grind, and crushed stone, although most of these small quarries have been abandoned. Several untapped sandstone hills and the Berlin Heights escarpment appear to be potential sources of quarry stone.

Some controversy has developed concerning the channel fills in basal portion of the Berea Sandstone. The "channels" have had several explanations. Burroughs (1911) interpreted irregularities in the Berea, such as the deep quarries at South Amherst, Lorain County, Ohio, as channels excavated into the underlying strata and filled with sands. Cushing et al. (1931) noted that shales at the base of the Berea are often highly disturbed (tilted and faulted) in the vicinity of large channels and concluded that these disturbances "were effected by the currents that brought in the Berea sands, the underlying mud being shifted about and slumping along the channel sides." Pepper et al. (1954) considered the channels to be deep valleys cut into the underlying shales and filled from the north during the deposition of the Berea delta. Lewis (1976,1988) interpreted the "channels" as synsedimentary (accompanying deposition; contemporaneously formed) slumps in a marine distributary system that were built from the east or southeast. He also suggested that the upper part of the Berea sandstone may have originated as eolian dunes. Burrows (1988) disagreed with Pepper et al. by identifying the "channels" as localized slumps into the Bedford Shale. Wells et al (1991), while not denying the presence of some channels in the Berea and slumps initiated by cutting and/or loading along channel axes, concluded that most "Berea channels" are primarily mass movements of sand into mud, supporting the view of Lewis (1988).

In north central Ohio the Berea Sandstone exhibits numerous structural anomalies (Herdendorf and Struble 1975). Local and in some cases intense deformation has occurred along the northern outcrop of this formation, whereas a few kilometers to the south the beds are only gently warped. The most striking structural features are found between the Huron and Vermilion Rivers in the valleys of Chappel Creek and Old Woman Creek. About 3 km north of Florence, at a place 120 m downstream from the Furnace Road bridge over Chappel Creek, overturning and faulting have jumbled the Berea Sandstone. Here the beds dip steeply (56°) to the south (S 20° W) while approximately 30 m father downstream the dip is only 10° in the same direction. The first outcrop of sandstone is 3 m thick and 15 m long, extending at a steep angle from the creek bed to the top of the bluff (Figure 2.31). The second, which is separated from the first by a covered interval of glacial till, is nearly the same thickness and persists from the stream bed to the top of the bluff.

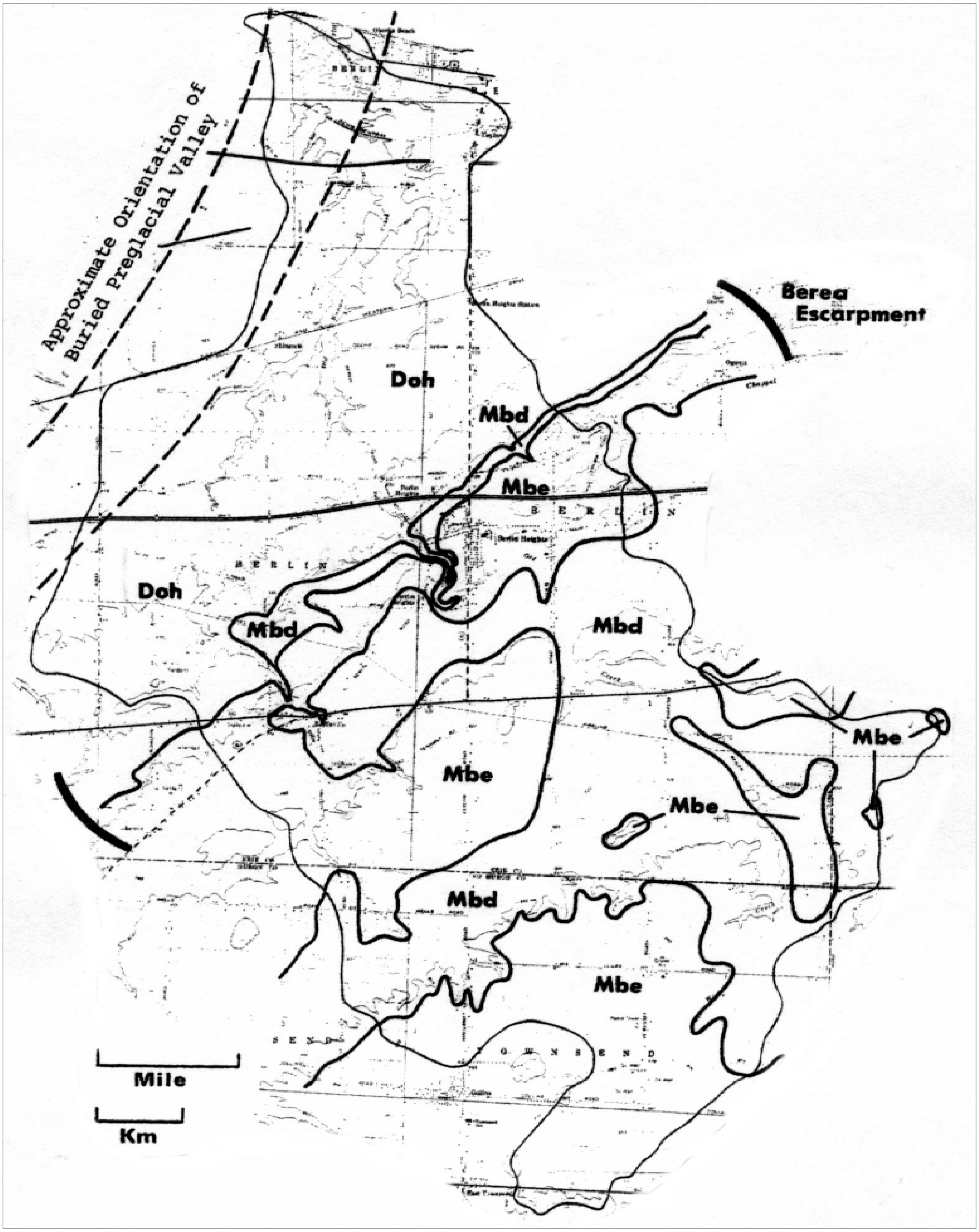


Figure 2.26. Geologic map of bedrock formations underlying Old Woman Creek watershed (from Herdendorf 1966, Buchanan 1982). Legend: Doh= Ohio Shale (Cleveland and Huron Shales), Mbd= Bedford Shale, Mbe= Berea Sandstone.

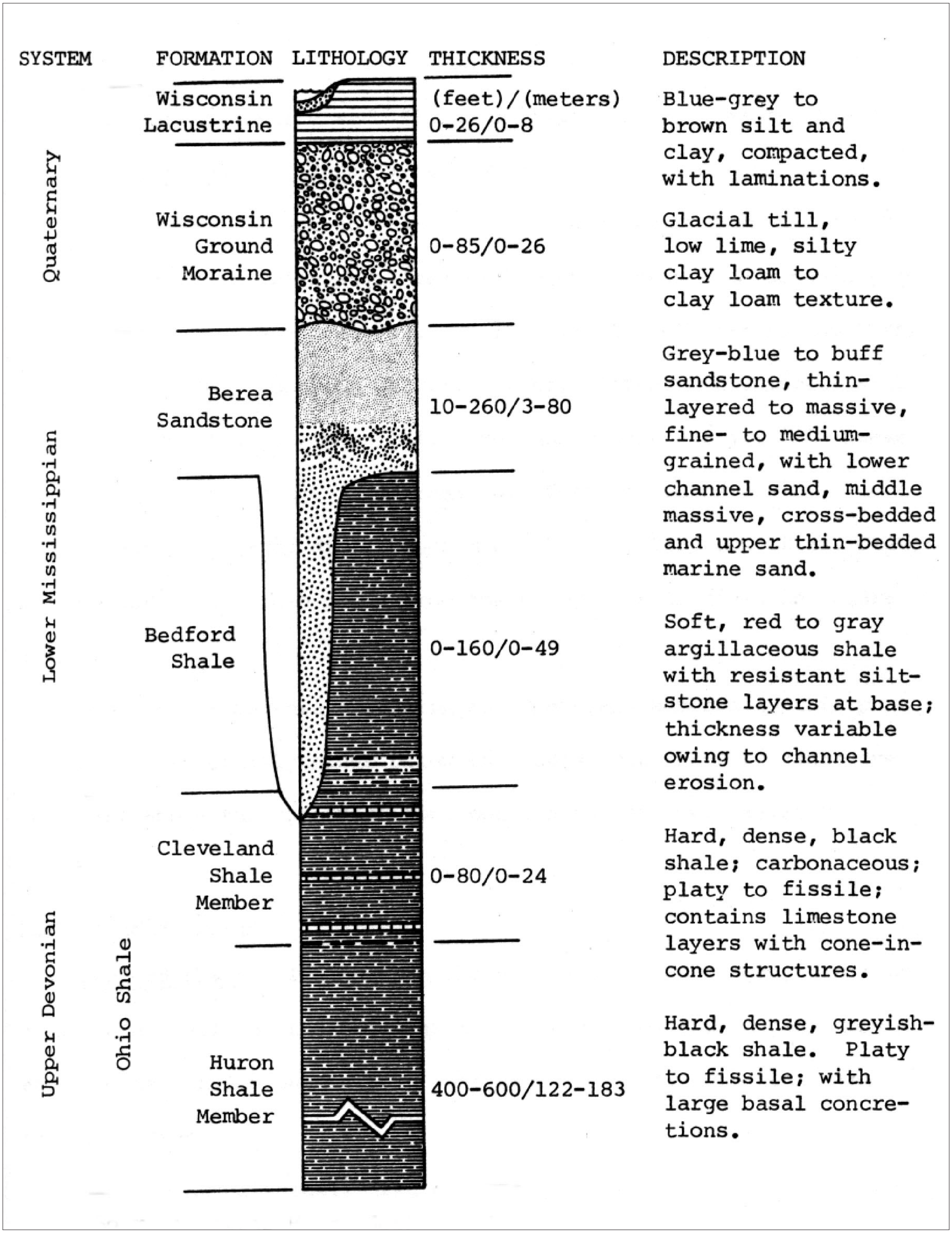


Figure 2.27. Stratigraphic column of bedrock formations exposed in Old Woman Creek watershed (from Herdendorf 1966, Buchanan 1982).

Figure 2.28. Berea Sandstone channel (top) into Ohio Shale (bottom) at Berlin Heights ravine (Charles E. Herdendorf).

Figure 2.29. Flow roll in Berea Sandstone at west wall of Berlin Heights ravine (Charles E. Herdendorf).

Figure 2.30. Oscillation ripple marks in Berea Sandstone along the West Branch of Old Woman Creek north of Berlinville, Ohio (Charles E. Herdendorf).

Because the second outcrop has a more gentle dip it is nearly 100 m long (Figure 2.32). On close inspection of these outcrops, Herdendorf (1963b) concluded from up-side-down oscillation ripple marks and cross-bedding truncated downward that both outcrops were overturned strata; the first being overturned 124° and the second 170°. This overturning appears to be a very local phenomena—less than 100 m farther downstream (north) similar beds occur in a right-side-up position near the top of the bluff.

The explanation for these unusual bedrock structures may lie in the fact that in preglacial times the Berea Sandstone outcrop most likely extended across north central Ohio as a terrace-like landform, cut only by north-flowing streams. This feature must have presented a formidable barrier to ice movement. When it was eventually overridden, large blocks or slabs of sandstone may have been fractured and dislodged from the northern edge. Such a process may account for the overturned strata in the Chappel Creek valley (Herdendorf 1963b, 1966). As the force of the ice dislodged the slab, it could have been easily pushed or dragged across the surface of underlying clay shale formation (Bedford Shale). The slab may have moved only a short distance before being rolled over which may have caused the fracture separating the two blocks. The force of the frictional drag along the bottom surface of the ice sheet may have also caused the broken, rumpled, and faulted shale beds in the stream valleys between Lake Erie and the sandstone outcrop. Hartley (1962) observed similar structural features in the shale beds along the lake shore east of Vermilion, Ohio.

Bedford Shale. This shale formation is bluish-gray to pink to reddish-brown, clayey, plastic, soft, indistinctly bedded (Figure 2.33); thin basal and upper gray beds separated by thick red shale unit. Thin resistant lenses, concretionary siltstone to very fine sandstone, occur in the basal shale and form 7- to 15-cm ledges along exposure; particularly well developed along the Vermilion River in Florence Township. Locally, siltstone layers and thin red and gray shale laminations occur at the base of the gray shale; upper gray shale beds are somewhat arenaceous and contain sandy flow rolls. Red and gray shales are composed of quartz; illite, chlorite, kaolinite, and hematite which imparts color to red shales; siltstone layers contain angular to subangular grains of quartz and feldspar cemented by hematite, pyrite nodules, and a small

Figure 2.31. Overturned Berea Sandstone in valley of Chappel Creek, northwest Florence Township, Ohio (Charles E. Herdendorf).

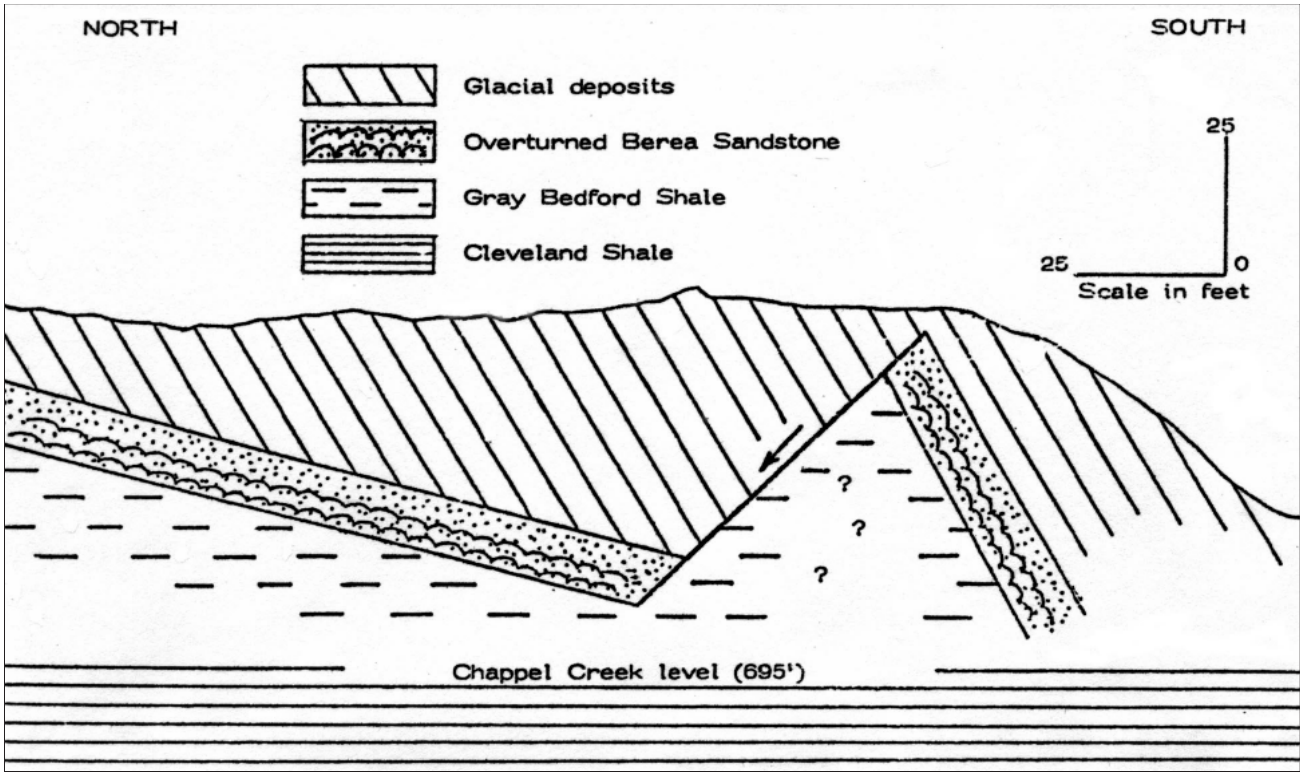


Figure 2.32. Cross-section of overturned Berea Sandstone in the valley of Chappel Creek (from Herdendorf 1963b).

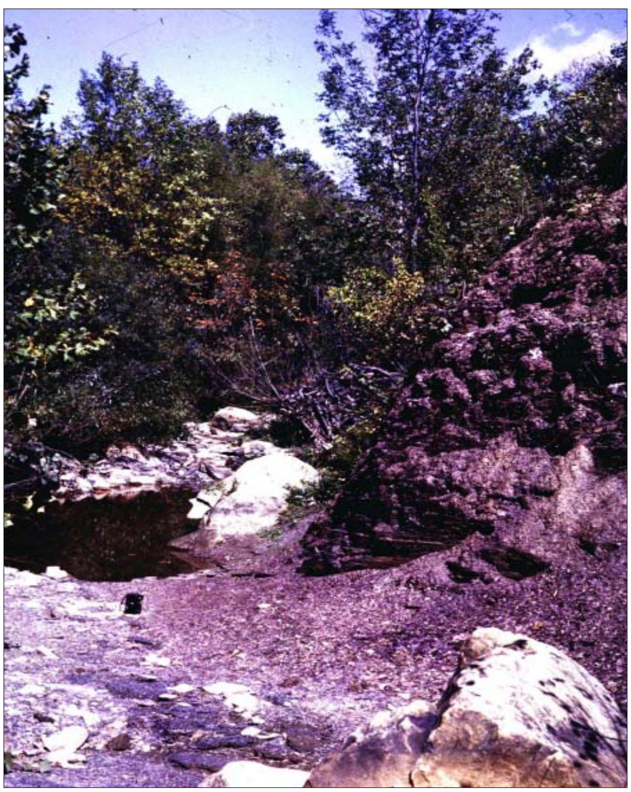


Figure 2.33. Red Bedford Shale in valley of Chappel Creek, Florence Township, Ohio (Charles E. Herdendorf).

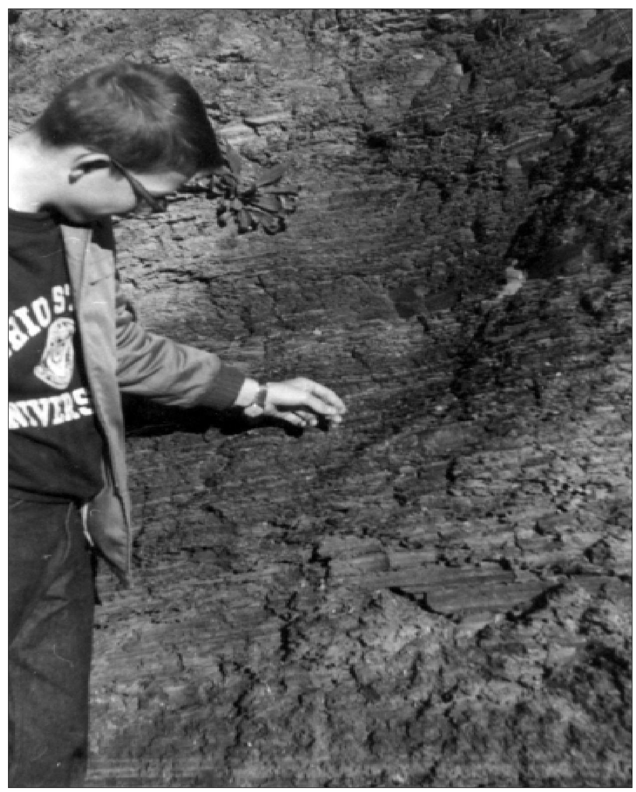


Figure 2.34. Laminated red and gray Bedford Shale beds, Henrietta Township, Ohio (Charles E. Herdendorf).

pelecypod, *Paleoneilo bedfordensis* Meek. Red shale weathers rapidly to sticky red mud that obscures outcrops by slumping, colors surface soil red, and often stains underlying outcrops. The thickness of this formation is highly variable due to pre-Berea erosion channeling. Red shale is not mined for ceramic purposes in Erie County, but similar deposits in Lorain and Cuyahoga Counties are producing clay shale for the brick and tile industry. Potential sources of clay shale are beds exposed along the Vermilion River and Chappel Creek in Florence Township (Figure 2.34).

Late Devonian Period

Within the Old Woman Creek watershed, the Late Devonian Period is represented by the Ohio Shale. This thick layer of rocks consists of two prominent members which underlie the northern portion of the watershed: the Cleveland Shale and the Huron Shale.

Cleveland Shale. This shale formation (Figure 2.35) is black, hard, dense, platy to fissile, abundantly carbonaceous; contains pyritic and septarian concretions and persistent limestone layers, 1 to 7 cm thick, characterized by cone-in-cone structure (Figures 2.36 and 2.37). Shale beds contain grains of quartz, pyrite, illite, and chlorite. Limestone is composed largely of calcite with argillaceous, pyritic, and hematitic material. Septarian concretions have fine matrix of quartz and clay minerals with veins of intergrown quartz, chalcedony, and pyrite crystals. Fresh chips of shale give off a petroliferous odor. Fossils are scarce; a few brachiopods, such as *Retichonetes aurora* (Hall) and *Orbiculoidea* sp., common in carbonaceous layers. Shale has pronounced vertical joint system at near right angles. Shale is resistant to weathering; weathered surfaces are brownish-gray to coffee color. Sulfate efflorescences are common on dry shale exposures. Best exposures of formation are along Vermilion River, Chappel Creek, and Old Woman Creek in Florence, Vermilion, and Berlin Townships.

Strata of the Bedford Shale and the Cleveland Shale formations in the vicinity of Old Woman Creek watershed typically dip to the southeast at approximately 4 to 5 m/km. In most exposures the shale beds appear nearly flat-lying or only gently warped. However, in the vicinity of sandstone channels or slump features, the shale beds are commonly folded,

Figure 2.35. Outcrop of Cleveland Shale along the West Branch of Old Woman Creek north of Berlinville, Ohio (Charles E. Herdendorf).

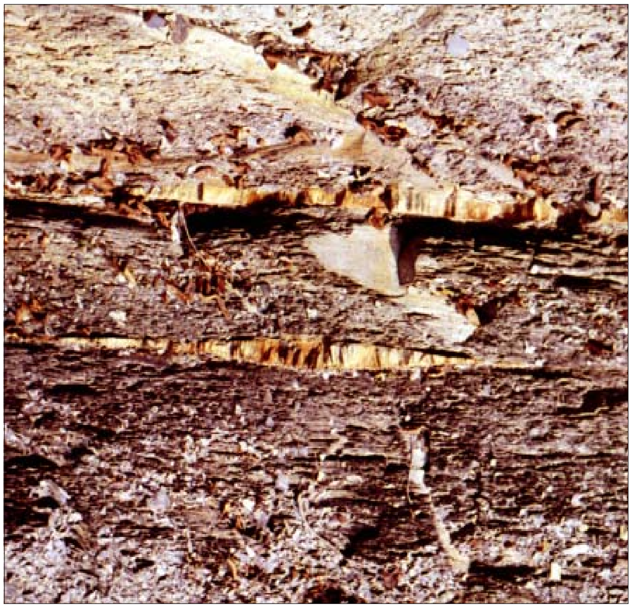


Figure 2.36. Lens of cone-in-cone limestone in the Cleveland Shale (Charles E. Herdendorf).

Figure 2.37. Limestone lens from Cleveland Shale showing detail of cone-in-cone structure (Charles E. Herdendorf).

faulted, and sometimes contorted or interbedded with the basal sands of the Berea Sandstone (Herdendorf and Struble 1975).

Huron Shale. This shale formation is grayish-black, hard, dense, platy to fissile; contains large concretions, 0.3 to 2 m in diameter, and septarian nodules in its lower part. Huron and Cleveland Shales are essentially identical in lithologic character; and in Erie County the contact between these two black shales has been arbitrarily drawn below the lowest cone-in-cone limestone layer and above the uppermost zone containing large concretions (Hoover 1960). Upper part of Huron Shale, and possibly lower part of Cleveland Shale, is interstratified with thin, soft, clayey, less resistant, bluish-gray shale beds which probably represent a minor western interfingering of Chagrin Shale which separates the two black shales in northeastern Ohio. Huron Shale is best exposed along the Huron River in the vicinity of Milan where large concretions can also be observed. Other outcrops include the Lake Erie bottom west of Huron at Boulder Shores (which receives its name from the large concretions in the shale), the bluffs of Sawmill Creek west of Huron (Figure 2.38), and the lake bluffs immediately east of Vermilion.

Subsurface Bedrock Formations

Middle Devonian Period

Prout Limestone. This limestone formation is dark gray to bluish-gray to blue, very hard, siliceous, fossiliferous. Formation is divided into four parts: (1) basal compact, crystalline, bluish-gray limestone, (2) soft shaly blue limestone with numerous silicified bryozoans, corals, and crinoid stems, (3) compact, hard, crystalline, gray limestone, and (4) dark gray to black chert layer with pyrite at top. Brachiopods *Atrypa reticularsis* and *Stropheodonata demissa* are common in the soft blue limestone. Prout limestone is exposed at "Slate Cut" in northwestern Huron Township, along Plum Brook and "Deep Cut" inside the NASA property in Perkins Township, east of Bloomingville, along Pipe Creek in Oxford Township, and at Strong's Ridge in

Figure 2.38. Concretion (80 cm diameter) in the Huron Shale, Sawmill Creek west of Huron, Ohio (Charles E. Herdendorf).

southern Groton Township. Quarrying, on a limited scale, has been done at the latter two locations (about 20 km west of Old Woman Creek watershed). Chert from this formation was used by early native inhabitants for tools and weapon points.

Plum Brook Shale. This shale formation is blue, soft, argillaceous, fossiliferous; contains thin layers of dark, hard, fossiliferous limestone. The lower portion contains layers of hard nodules which are often pyritic. Numerous pyrite crystals occur in the beds exposed at the Norfolk & Western Railroad cut at Bemis Road in southern Groton Township in Erie County. Other exposures are located on Plum Brook in the NASA property and along Pipe Creek east of Bloomingville. Common fossils include trilobite *Phacops rana*, brachiopods *Spirifer pennatus*, *Chonetes deflectur*, and *Stropheodontal*; corals *Favosites* and *Zophrentis*, and bryozoan *Fenestealla*. Formation rapidly weathers to marly, blue clay shale which obscures outcrops. Shale may have potential ceramic value. Prehistoric native Americans may have used a near-lithographic limestone member of this formation as stone from which pipes were carved. This “pipestone” is believed to have been quarried by early inhabitants north of Hunt Creek in Groton Township.

Delaware Limestone. This limestone formation is dark to bluish-gray, thin-bedded to massive, with calcareous shale partings; siliceous, dense, tough, durable and contains some chert. Composition of rock is that of an impure limestone. Limestone is of marine origin and fairly fossiliferous. Delaware Limestone ranks as a good building stone and has also been used for crushed stone and concrete aggregate. This stone is presently being quarried in Perkins and Groton Townships of Erie County. Several outcrops occur from the east side of Sandusky southeast to Bellevue, generally at old quarry sites.

Columbus Limestone. This limestone formation is light gray to buff, moderately thin-bedded to massive crystalline, locally dolomitic and somewhat earthy in appearance. Cherty layers and nodules also occur locally. Columbus Limestone has been taken in past years from two quarries in Margaretta Township as well as from the two quarries mentioned in the Delaware Limestone discussion. Outcrops occur southeast of Sandusky and Castalia as well as eastern Kelleys Island where large grooves clearly show the glaciated surface of the Columbus Limestone.

Early Devonian Period

The subsurface rocks underlying the watershed from the Early Devonian Period are represented by two formations within the Detroit River Group: the Lucas Dolomite and the Amherstburg Dolomite.

Lucas Dolomite. This dolomite (dolostone) formation is gray to brown drab, thin-bedded to massive, carbonaceous parting common between layers, locally calcareous, and very resistant. Fresh surface often yields strong petroliferous odor. Formation has been quarried for crushed stone, fluxstone, and concrete aggregate in the two above operations in Margaretta Township and is now being worked in a quarry on western Kelleys Island. Outcrops are limited because of the mantle of glacial drift.

Amherstburg Dolomite. This dolomite formation is drab to brown, open or even cavernous in texture, massive bedding, resistant. Rock is true dolomite in composition. Exposures are obscured in Erie County owing to the thickness of glacial drift.

Late Silurian Period

Below the Detroit River Group strata another group of dolomites, Bass Island Group, occurs. This deeper group includes the Raisin River Dolomite, Put-in-Bay Dolomite, Tymochtee Dolomite, and the Greenfield Dolomite.

Raisin River Dolomite. This dolomite formation is blue-gray to drab, thin-bedded to shaly, argillaceous. Stone is fairly pure dolomite. Glacial drift and lake sediments mantle the formation in Erie County. Part of northwestern Margaretta Township is probably underlain by Raisin River Dolomite.

Put-in-Bay Dolomite. This dolomite formation is gay-to-drab-to-light-brown, medium bedded, rough textured, crystalline, weathers with irregular knobby surface. Composition of the stone is a dolomite of fair purity. Best exposure in Erie County is Crystal Rock Spring in northwestern Margaretta Township. Glacial drift mantles most of this formation.

Tymochtee Dolomite. This dolomite formation is dark bluish-gray to brown, thin-bedded to shaly, calcareous shale partings, contains gypsum and anhydrite. Dolomite in thin layers is coarse grained, fairly tough, moderately homogeneous, and composition approaches that of a true dolomite. Occurs in western Margaretta Township. Outcrops obscured by glacial drift.

Greenfield Dolomite. This dolomite formation is bluish-gray to light drab to dark brown, thin bedded to massive, generally dense and hard, but some layers are granular or vesicular. Underlies western Margaretta Township, under Sandusky Bay, but is deeply buried by glacial drift and bay sediments.

Evolution of Lake Erie: Glacial and Postglacial Lakes

Lake Erie owes its origin to physiographic changes induced by Late Cenozoic (Pleistocene) glaciers. During the long time interval between the deposition of Paleozoic sediments and the first glacial advance (250 million years), erosive forces cut a mature drainage system into the rocks that underlie present Lake Erie (Figure 2.39). As advancing or retreating ice sheets paused, ridges (or moraines) of glacial till were built up at the ice margins, damming the natural drainage. Large glacial lakes formed between the moraines and the ice front (Figure 2.40). Lake Erie and Old Woman Creek estuary are remnants of a series of glacial lakes that, at its earliest and highest stage, extended as far southwest as present day Fort Wayne, Indiana and drained in that direction via the Mississippi River system. As the ice retreated from this position other outlets were uncovered and new lake stages were formed at successively lower elevations. In a few instances readvances of the ice blocked outlets and temporarily caused higher lake levels. Sandy beach ridges and wave-cut cliffs, 2 to 7 km inland of the estuary, mark the position of these former lakes (Figure 2.41).

When the last glacier retreated from the Niagara River area a new and final outlet was available at present-day Buffalo, New York. Initially this outlet was at a considerably lower elevation than at present because of crustal depression under the weight of the glacial ice. Thus, the last glacial lake quickly drained through this new opening and much of the present bed of Lake Erie was dry for an extended period. Eventually the Niagara outlet began to rebound from its depressed position and modern Lake Erie was formed as the lake waters flooded the shore and tributary mouths, creating freshwater estuaries. The chronology and elevations of the glacial and postglacial lake stages in the Erie basin are illustrated in Figures 2.42 and 2.43. The following section will describe the Lake Erie evolution process in more detail and discuss how it influenced the geologic history and existing landforms in the vicinity of Old Woman Creek.

For more than a century researchers such as Spencer (1891,1894), Leverett (1902), Carney (1911), Leverett and Taylor (1915), Bretz (1953,1964), Hough (1958,1962,1963,1966), Hartley (1958,1961b), Forsyth (1959,1973), Goldthwait et al. (1961,1965), Dreimanis (1964,1969), Lewis et al. (1966), Herdendorf (1968), Lewis (1969), Calkin (1970), Calkin and Feenstra (1985), Dorr and Eschman (1970), Prest (1970), Dreimanis and Karrow (1972), Herdendorf and Braidech (1972), Terasmae and Dreimanis (1976), Karrow and Calkin (1985), Larsen (1987,1994), Herdendorf and Bailey (1989), Pengelly et al (1997), Coakley et al. (1999), Holcombe et al. (1999), and Lewis et al (1999a,b) have contributed materially to understanding the sequence of events which have taken place in the evolution of Lake Erie. The lake chronology begins about 14,500 YBP when the last Pleistocene glacier, known as the Wisconsinan ice sheet, temporarily halted in its retreat. Although the ice front was in a stationary position over northwest Ohio, northeast Indiana, and southeast Michigan (rate of ablation and rate of advance in equilibrium), forward transport of drift continued under the ice, creating the Fort Wayne end moraine at the ice margin (Figure 2.44). The position of this moraine lies approximately along the drainage divide between the St. Lawrence River and Mississippi River systems, about 30 km southwest of the Old Woman Creek drainage basin. As the ice eventually retreated from the Fort Wayne moraine, water was ponded between the ice front and the moraine, thus starting a 2,000-year sequence of glacial lakes in the Erie basin.

Glacial Lake Maumee (14,400–13,800 YBP)

Lake Maumee was the first of the large glacial lakes to form in the Erie basin as the ice retreated. Lake Maumee had three, or possibly four, stages (water levels) in response to minor ice advances and retreats which altered the lake's outlet (Calkin and Feenstra 1985). The highest stage (Lake Maumee I) had a surface elevation of 244 m (800 ft) above sea level

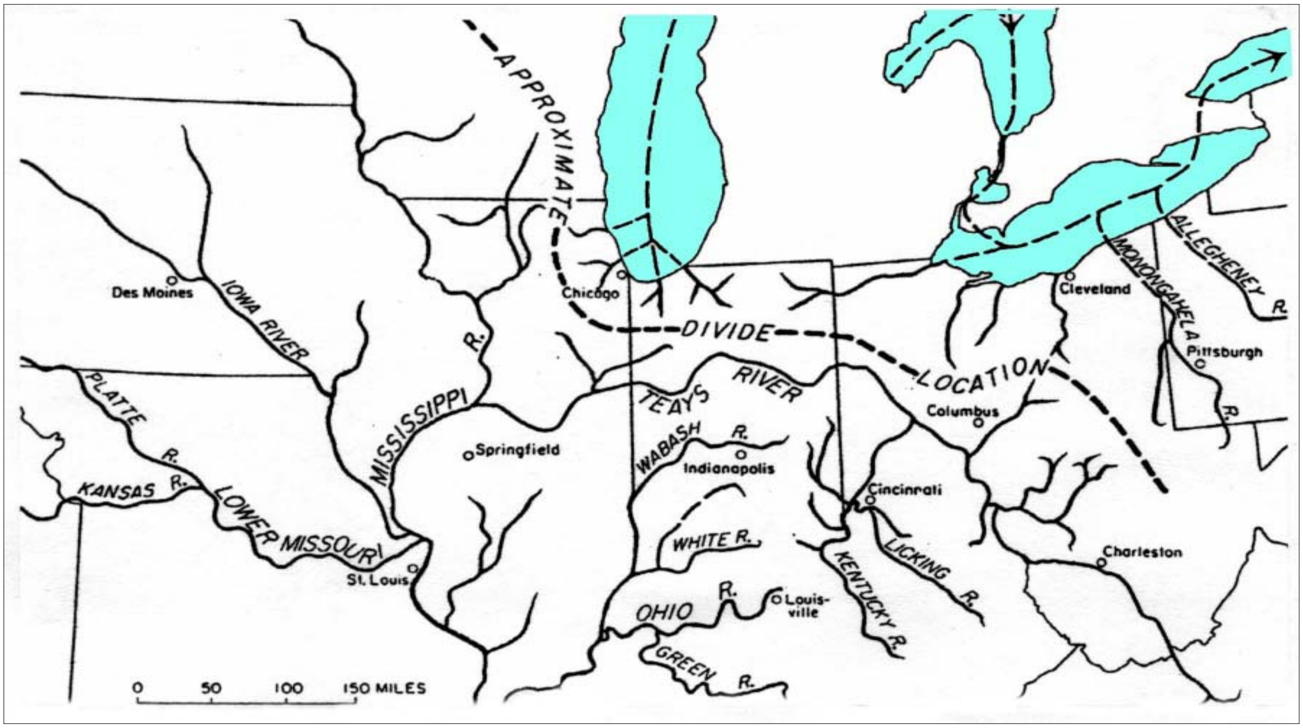


Figure 2.39. Preglacial drainage patterns in southern Great Lakes Basin (from Thornbury 1965).

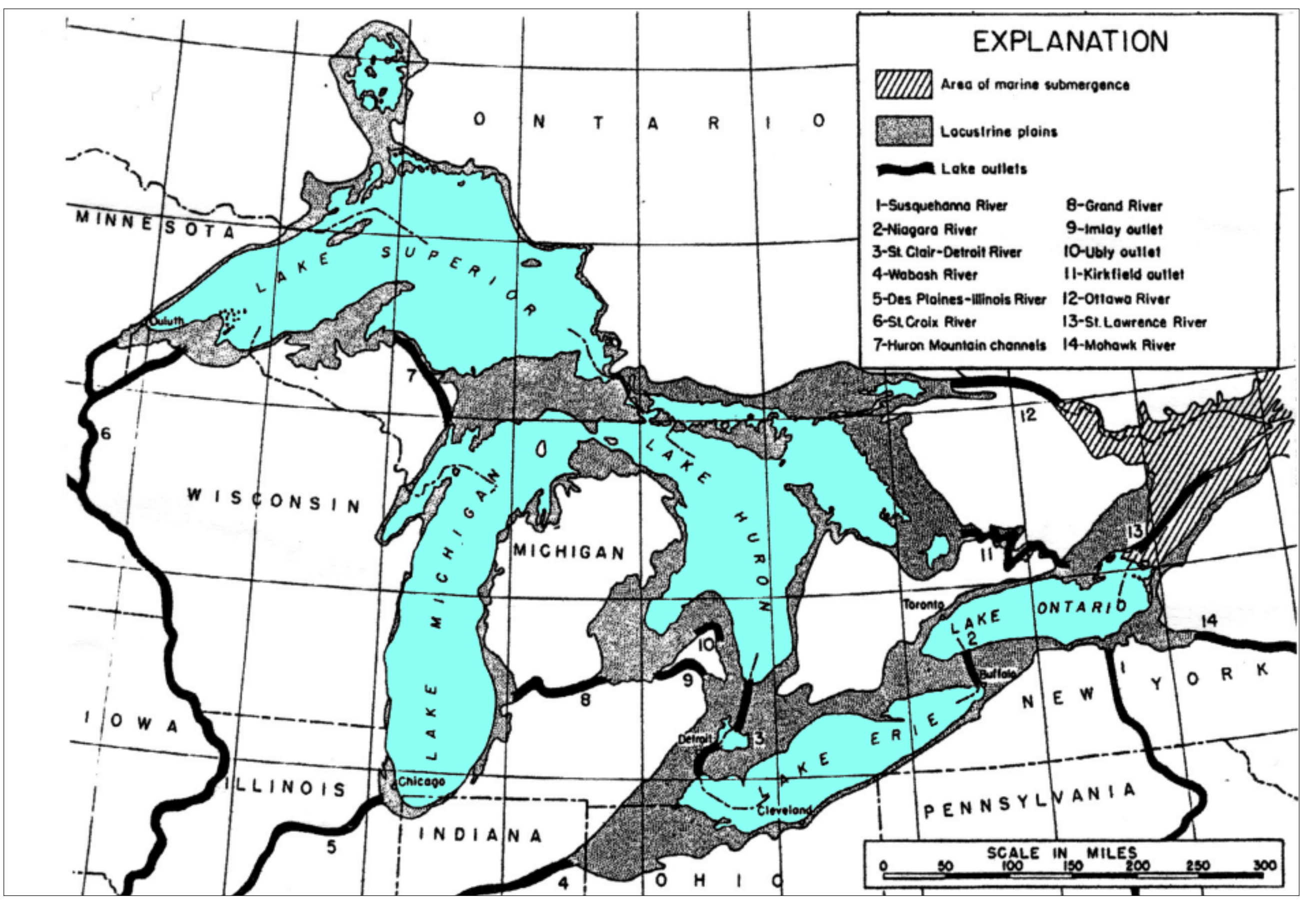


Figure 2.40. Extent of glacial lakes in the Great Lakes basin, showing outlets (from Leverett and Taylor 1915).

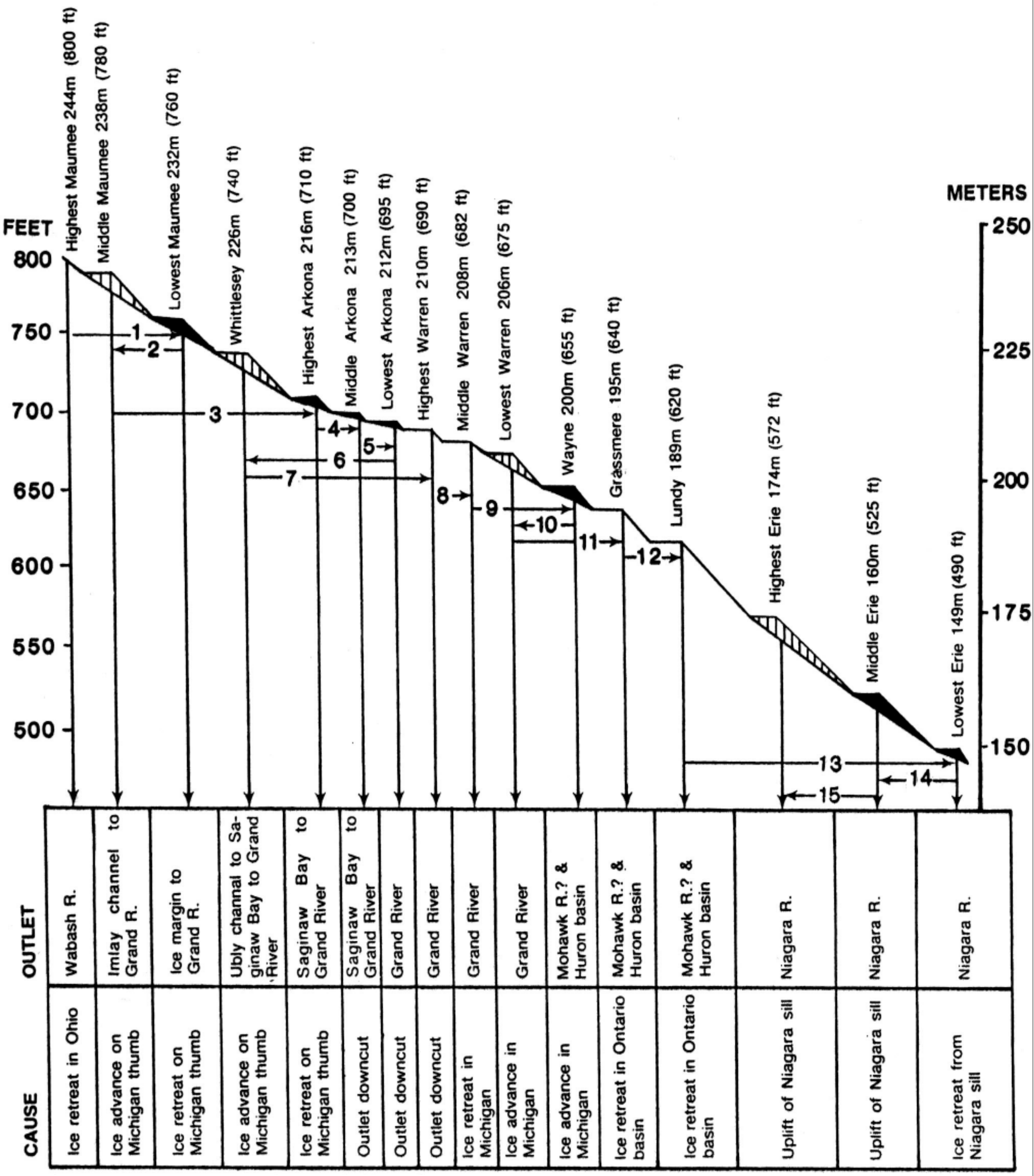


Figure 2.41. Number sequence of glacial beach ridges in the vicinity of Old Woman Creek. Note: beaches shown in black were submerged, after formation and partially destroyed; beaches with vertical lines were not submerged after formation and are more prominent features of the present landscape (from Hartley 1958).

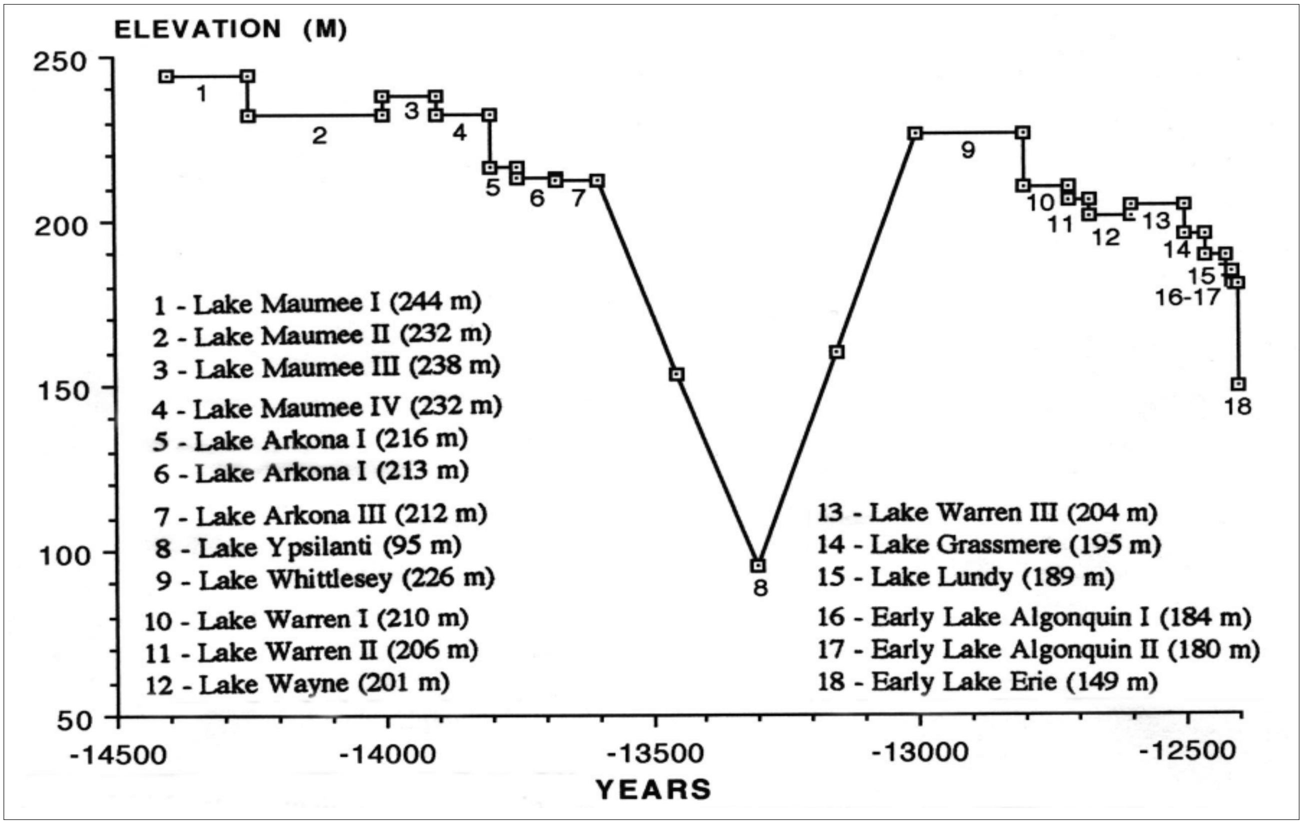


Figure 2.42. Glacial lake stages in the Erie basin, elevations in meters above sea level (modified from Calkin and Feenstra 1985).

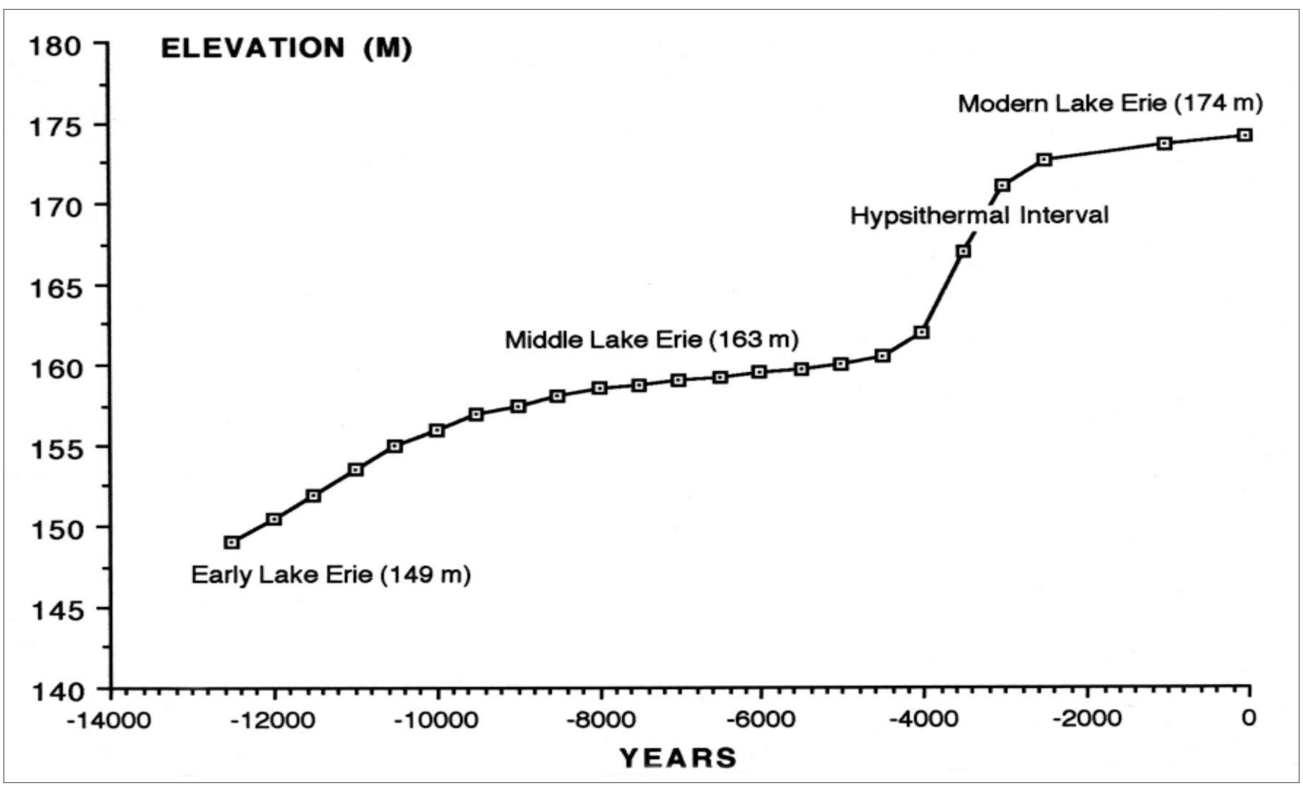


Figure 2.43. Postglacial lake stages in the Erie basin (modified from Herdendorf and Bailey 1989).

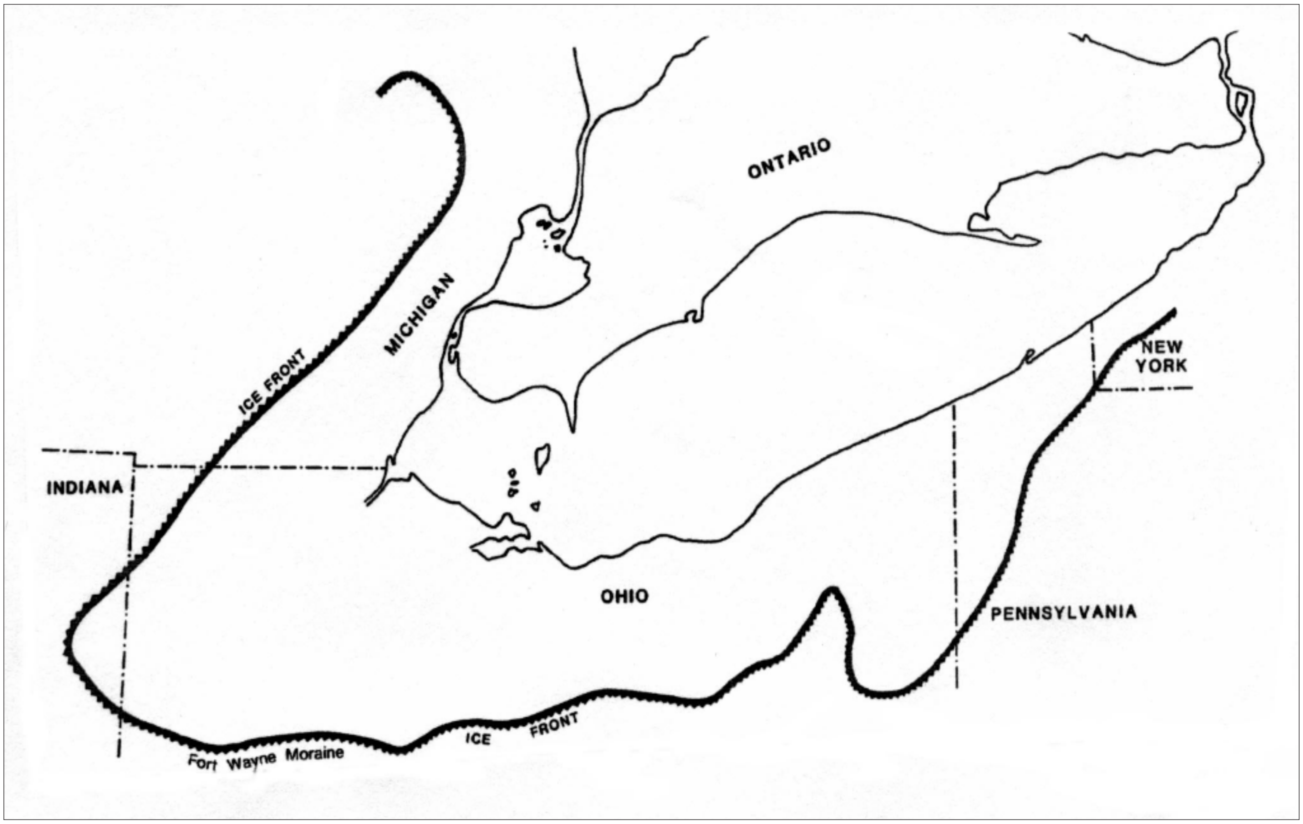


Figure 2.44. Wisconsinan glacial ice front immediately prior to the beginning of glacial lake stages in the Lake Erie basin (from Herdendorf 1989).

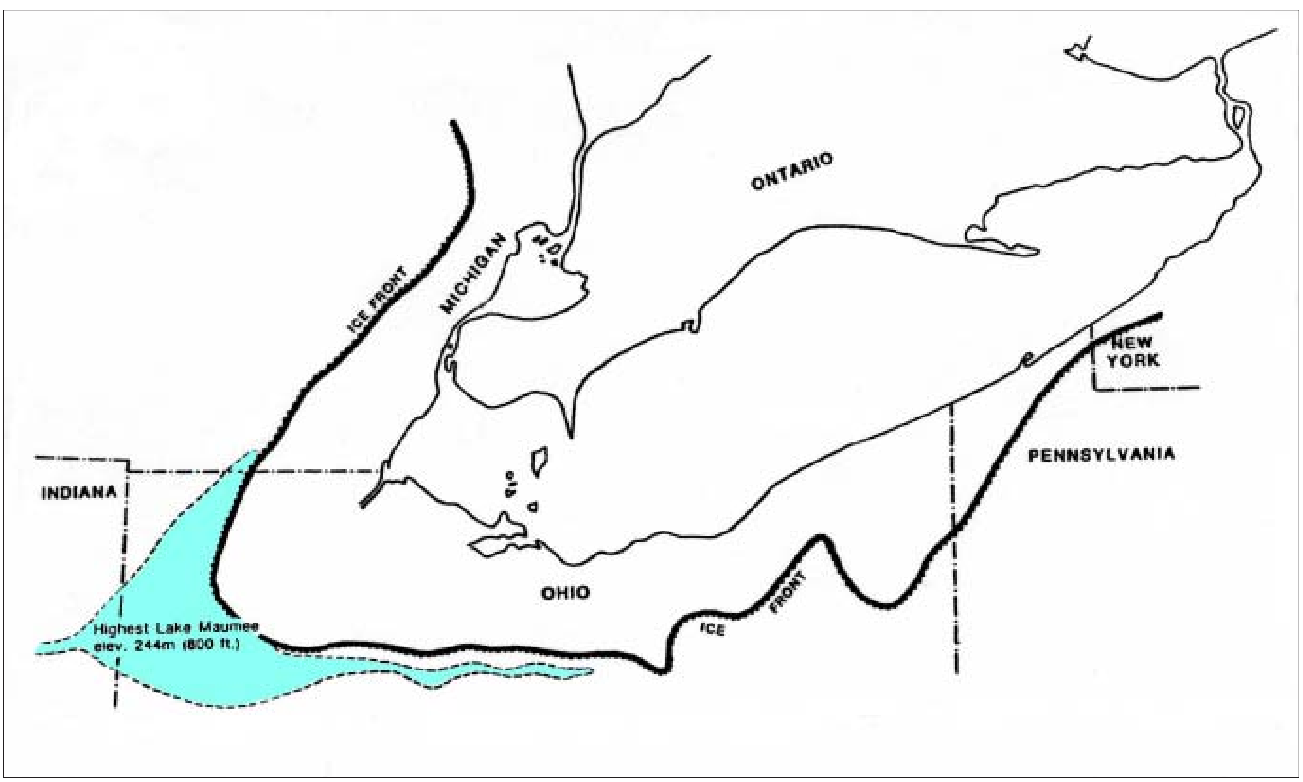


Figure 2.45. Glacial Lake Maumee I, highest Maumee stage (from Herdendorf 1989).

and occurred while the ice front was again stationary in northwestern Ohio, creating the Defiance moraine, some 20 to 30 km farther north of the Fort Wayne moraine (Figure 2.45). The outlet for this stage was to the southwest at Fort Wayne, Indiana via the Wabash-Ohio-Mississippi rivers to the Gulf of Mexico. The maximum water depth of Lake Maumee I was about 30 m. With a surface area of 5,000 km^2, this was the smallest glacial lake stage in the Erie basin. Because the ice front was still at least 10 km south of Norwalk, Ohio this stage is not represented by beach ridges or lake cliffs in the Old Woman Creek watershed. However, Campbell (1955) suggested that as the ice front retreated from the Defiance moraine, Lake Maumee I was enlarged and elongated to the east before the initiation of the next lake stage. Isolated sand ridges and a sizable dune field about 2 to 3 km southeast of Berlin Heights, at elevations ranging from 244 m to 247 m (800 to 810 ft), may be evidence of this stage within the Old Woman Creek watershed.

The second and lowest stage (Lake Maumee II) had a surface elevation of 232 m (760 ft) (Figure 2.46). This stage resulted from renewed ice retreat in Michigan which opened an outlet to the west at Imlay via the Grand River to Lake Chicago in the Lake Michigan basin (Figure 2.40). Bottom deposits in the Erie basin (e.g. sand and gravel on a glacial till ridge) indicate that during this stage the ice front stood between Point Pelee, Ontario and Avon Point, Ohio (Pelee moraine), and then hooked to the east northeast as marked by the Euclid-Lake Escarpment moraine in northeastern Ohio (Goldthwait et al. 1961). Another lobe of ice apparently stood in the Lake Erie islands area at the same time, the front extending from Point Pelee southwest to Catawba Point, Ohio and then northwesterly toward the present mouth of the Detroit River (Hartley 1958,1961b). The lowest elevation of the till surface under Lake Maumee II was found by seismic surveys to be about 143 m (470 ft) in a depression 15 km north of the present Old Woman Creek mouth (Hobson et al. 1969), yielding a maximum water depth of 89 m (290 ft) for this glacial lake stage. This stage of Lake Maumee had a surface area of approximately 19,000 km^2.

In the vicinity of Old Woman Creek, Lake Maumee II is represented by an intermittent, sandy beach ridge that traverses the watershed in a northeasterly direction from 1 km west of Berlinville to 2 km northeast of Berlin Heights. North of the latter village, and Mason Road, the ridge is about 15 m below the crest (lakeward side) of the Berea Escarpment and is more or less continuous at an elevation of 232 m (760 ft) into the valley of Chappel Creek.

The third and mid-elevation stage (Lake Maumee III) had a surface elevation of 238 m (780 ft) (Figure 2.47). The rise in lake level is attributed to a minor readvance of the ice front in Michigan which allowed the lake to drain through both the Imlay channel to the Grand River in Michigan and the Fort Wayne channel to the Wabash River in Indiana (Figure 2.40). The ice front in the Erie basin had retreated to a temporary pause north of Cleveland (Erieau moraine) and then halted north of the Ohio-Pennsylvania line, creating a large end moraine. This feature, known as the Norfolk moraine, is marked by a very wide sand and gravel ridge which extends from near Erie, Pennsylvania to the base of Long Point, Ontario (Sly and Lewis 1972). Because of the massive size of the moraine, the ice front apparently occupied this general position during several of the ensuing glacial lake stages. The lowest elevation of the undissected till surface under Lake Maumee III was found by seismic surveys to be about 98 m (320 ft) in a broad depression about 100 km northeast of the present Old Woman Creek mouth (Wall 1968), yielding a maximum water depth of 140 m (460 ft) for this lake stage. Lake Maumee III had a surface area of approximately 42,000 km^2 and was the largest of the Maumee glacial lake stages.

In the vicinity of Old Woman Creek, the Lake Maumee III stage is represented by a prominent sand ridge upon which Ohio Route 61 was built southeast of Berlinville, Berlin Road between Berlinville and Berlin Heights, and Mason Road northeast Berlin Heights. At an elevation of 238 m (780 ft), the Lake Maumee III ridge lies slightly to the south of, parallel to, and at some places merges with the less pronounced Lake Maumee II beach deposits. Where Humm Road intersects Mason Road (near the eastern edge of the Old Woman Creek drainage basin) a massive outcrop of Berea Sandstone forms an escarpment that reaches an elevation of 259 m (850 ft) which precluded the development of beach ridges. However, at elevations of approximately 237–240 m, the exposed rocks show evidence of wave cutting and undermining. Dissection of the sandstone hills along the northern edge of the escarpment strongly influenced the Lake Maumee shoreline, resulting in embayments with numerous rocky islands, sand spits, and dunes (Figure 2.18).

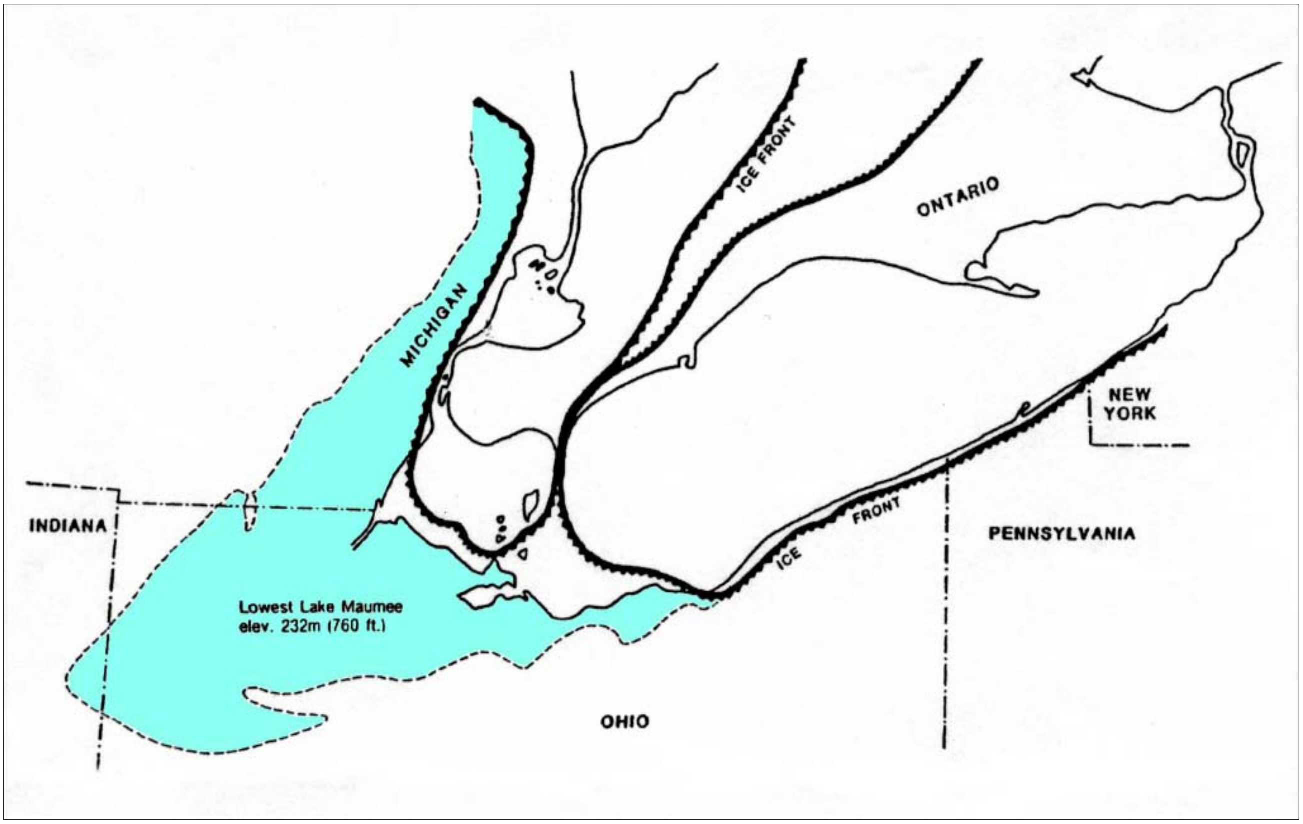


Figure 2.46. Glacial Lake Maumee II and Lake Maumee IV, lowest Maumee stages (from Herdendorf 1989).

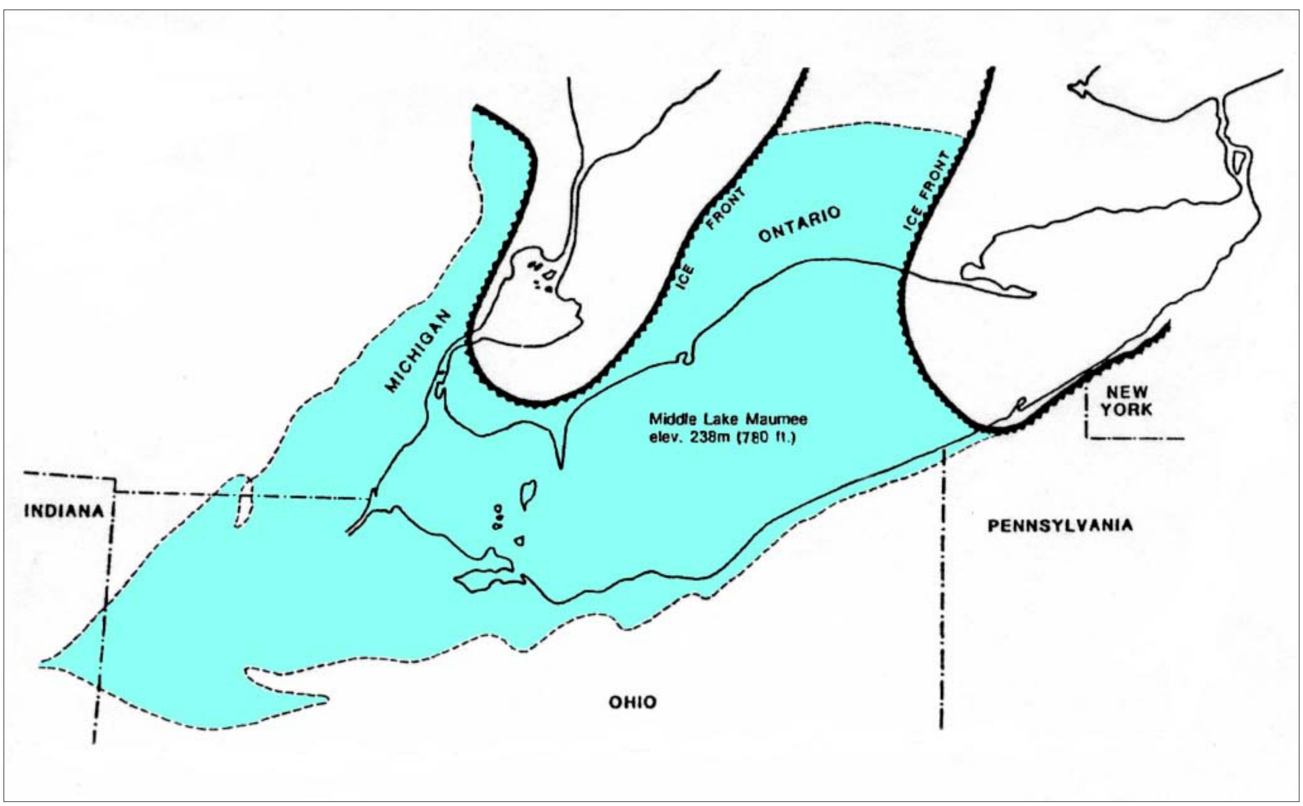


Figure 2.47. Glacial Lake Maumee III, middle Maumee stage (from Herdendorf 1989).

Wave erosion of these sandstone outcrops and the moraines furnished much of the sand for building the adjacent beach and dunes (Herdendorf 1963b).

In the Chappel Creek drainage basin (watershed to the east of Old Woman Creek) an abandoned stream valley, known as Florence Valley, was formed as a result of the capture of a tributary of the Vermilion River during the time of Lake Maumee III (Hole and Redmond 1970). The capture of the former west fork of the Vermilion River increased the length of the ancestral Chappel Creek by nearly 3-fold.

A fourth stage (Lake Maumee IV) has been postulated by Fullerton (1980) at the same elevation as Lake Maumee II, elevation 232 m (760 ft). Lowering the lake to this elevation can be explained by downcutting of the outlet channels which thereby dropped the level of the lake. This reoccupation hypothesis appears to have some merit based on the notable beach ridges found in the vicinity of Berlin Heights at the Maumee II/IV elevation. Normally when a lake raises in elevation, beaches formed at a lower level are destroyed, as would have been expected in the case of Lake Maumee III raising 6 m (20 ft) over the previous Maumee II level. However, if following Lake Maumee III, the old Maumee II level was reoccupied then a beach would be rebuilt at the old level and would not be later destroyed by overtopping. The gradual erosion of the outlet channels would also help to explain the merging of the Maumee II and Maumee III beach ridges described above.

GLACIAL LAKE ARKONA (13,800–13,600 YBP)

Lake Arkona was created when renewed ice retreat in Michigan allowed water to flow into Saginaw Bay forming a continuous lake in both the Erie and Huron basins. Lake Arkona drained to the west via the Grand River (Figure 2.40). Downcutting of the outlet (Hough 1958) or isostatic events and climate-related changes in the water budget (Larsen 1985a,b) resulted in three lake stages at surface elevations of 216 m (710 ft), 213 m (700 ft), and 212 m (695 ft), known as respectively as Lake Arkona I, II, and III. During this time the ice front also retreated to the northeast as evidenced by three beaches in northwestern Pennsylvania (Calkin and Feenstra 1985). Because Lake Arkona also extended into the Huron basin (Saginaw Bay area), it had a surface area of 74,000 km^2 and was one of the largest glacial lakes to form in the Erie basin. The maximum depth of this stage was about 118 m (387 ft).

In the vicinity of Old Woman Creek, Lake Arkona beach deposits have been mapped at the 216-m (710-ft) elevation in Vermilion Township, east and west of Joppa Road (Herdendorf 1966). No other Lake Arkona beaches have been reported in Erie County, but wave-cut features, at the elevations of the lower Lake Arkona stages, occur in the shale bedrock along the lower part of the Berea Escarpment between the valleys of Old Woman Creek and Chappel Creek (Carney 1911). The poor representation of Lake Arkona (e.g. beach ridges) can be explained by subsequent lowering (to Lake Ypsilanti level) and then raising of the water in the Erie basin to an even higher elevation (to Lake Whittlesey level) which caused most of the beach ridges to be destroyed by wave action.

LAKE YPSILANTI (13,600–13,000 YBP)

General ice retreat throughout the Great Lakes region brought an end to Lake Arkona. The ice may have retreated far enough to the east at this time to uncover very low outlets in that direction which resulted in the first nonglacial lake in the Erie basin, known as Lake Ypsilanti (Kunkle 1963). Some researchers place this low-water stage between Lake Arkona I and II (Dorr and Eschman 1970). The buried St. David Gorge (northwest of the Niagara River whirlpool) may have been cut into the Niagara Escarpment at this time as an outlet for the low lake stage (Forsyth 1959) and subsequently filled with drift when the glacier readvanced to create Lake Whittlesey. Sub-bottom seismic reflection surveys by Wall (1968) showed a channel cut to an elevation of 79 m (260 ft) in the glacial till about 120 km east northeast of Old Woman Creek. This implies that the weight of glacial ice depressed the Niagara Escarpment 95 m (310 ft) below its present elevation. This magnitude of depression is also indicated by isostatic adjustments as measured by warping in Lake Maumee strandlines in Michigan, but it is about twice the amount that can be explained by Lake Arkona warping (Leverett and Taylor 1915), leaving a question as to the level of the low water stage. In any case, the Lake Ypsilanti channel is believed to be cut into Port Stanley till (deposited by retreating ice during Lake Maumee) and filled with lake clays deposited in Lake Whittlesey and later glacial lake stages (Calkin and Feenstra 1985). The channel cut into the till is less than 8 km wide at its maximum extent. Therefore, Lake Ypsilanti was probably a long, narrow lake about 30 m (100 ft) deep in the central part of the Erie basin, but may have flared out to a broader lake in the eastern end of the basin as indicated by the deeper till surface. Lake Ypsilanti's surface area was probably less than 5,000 km^2. The Port Huron glacial readvance closed the Niagara outlet and brought this low stage in the Erie basin to an end.

GLACIAL LAKE WHITTLESEY (13,000–12,800 YBP)

The Port Huron ice front reoccupied the Norfolk moraine area, blocking outlets to the east and transferring drainage to the west via Ubly channel in Michigan to Lake Saginaw and the Grand River (Figure 2.40). The elevation of this outlet at 226 m (740 ft) created glacial Lake Whittlesey (Figure 2.48). The most pronounced beach ridges, both in height and quantitiy of sand, in the Erie basin mark the former shoreline of Lake Whittlesey (Forsyth 1959). Beach ridges in northeastern Ohio reach a phenomenal height of 21 m (70 ft). This is remarkable considering that Lake Whittlesey only existed for approximately 200 years. Wave erosion of the Berea Sandstone along the Lake Whittlesey shoreline in northcentral Ohio appears to have contributed large quantities of beach-building material. Near the end of the Lake Whittlesey stage, the ice retreated somewhat in the eastern part of the Erie basin, resulting in only weakly developed beach ridges near Dunkirk, New York. Based on the elevation of the channel cut into the till off northeastern Ohio (Wall 1968), the maximum depth of Lake Whittlesey was about 147 m (482 ft), the deepest glacial lake in the Erie basin. With a surface area of 59,000 km^2, this was also the largest glacial lake confined primarily to the Erie basin.

In the vicinity of Old Woman Creek watershed, the Lake Whittlesey shoreline is generally parallel the Lake Maumee shoreline, but it is much more regular (Figure 2.18). Because of the steepness of the Berea Escarpment, the Maumee and Whittlesey shorelines are typically no more than 0.5 km apart. From the watershed boundary near Berlinville, northeast to Mason Road near Berlin Heights, the Whittlesey shoreline consists of a continuous sand and gravel ridge. As the escarpment becomes more prominent to the northeast, the shoreline is expressed as a wave-cut cliff in the Berea Sandstone. This feature continues to the eastern boundary of the watershed where sandy ridges resume and extend to the valley of Chappel Creek (Herdendorf 1966).

GLACIAL LAKES WARREN AND WAYNE (12,800–12,500 YBP)

Further ice retreat in the "Thumb" area of Michigan ended the Lake Whittlesey stage and initiated the Lake Warren sequence (Figure 2.49). Because ice still ocuppied the Niagara Escarpment, Lake Warren drained along the ice margin into Saginaw Bay and then westward via the Grand River. Lake Warren appears to have consisted of three stages: a high stage (Lake Warren I) at an elevation of 210 m (690 ft), a mid-elevation stage (Lake Warren II) at 206 m (675 ft), and a low stage (Lake Warren III) at 204 m (670 ft). Downcutting of the outlet appears to have caused the decreasing stage elevations. Between Lake Warren II and III, a short-lived low water stage existed with a radically different outlet. Known as Lake Wayne, this stage had an elevation of 201 m (660 ft) and may have drained eastward through the Mohawk River valley in New York (Hough 1958). Later, Hough (1963,1966) was less certain of an eastern outlet. However, only a minor retreat of the ice margin that held in Lake Warren would be needed at the Niagara Escarpment to allow drainage eastward via the Mohawk outlet. Fullerton (1980) suggested that the Lake Wayne stage may have been followed by a brief episode of an even lower lake level, when waters in the Erie basin fell to a level below the Niagara Escarpment. Eschman and Karrow (1985) pointed out that the subsequent rise in lake level to that of the lowest Warren stage (Lake Warren III), is best explained by advance of the ice margin which closed off the eastern outlet. Larsen (1985b) postulated that the rise in water level may have resulted from climatic changes so that Lake Warren III may have drained both east and west, simultaniously. Totten (1985) plotted radiocarbon dates for deposits from Lake Maumee to Early Lake Erie and noted a uniform and gradual rate of lake level decline through the Lake Warren stages, then another uniform but more rapid rate of decline from Lake Wayne to Early Lake Erie. He interpreted the break in slope as indicative of outlets being opened to the east. The Warren highest stage (Lake Warren I) was a large lake with a surface area of 62,000 km^2, including the Saginaw embayment (Eschman and Karrow 1985). The maximum depth in this stage was about 107 m (350 ft).

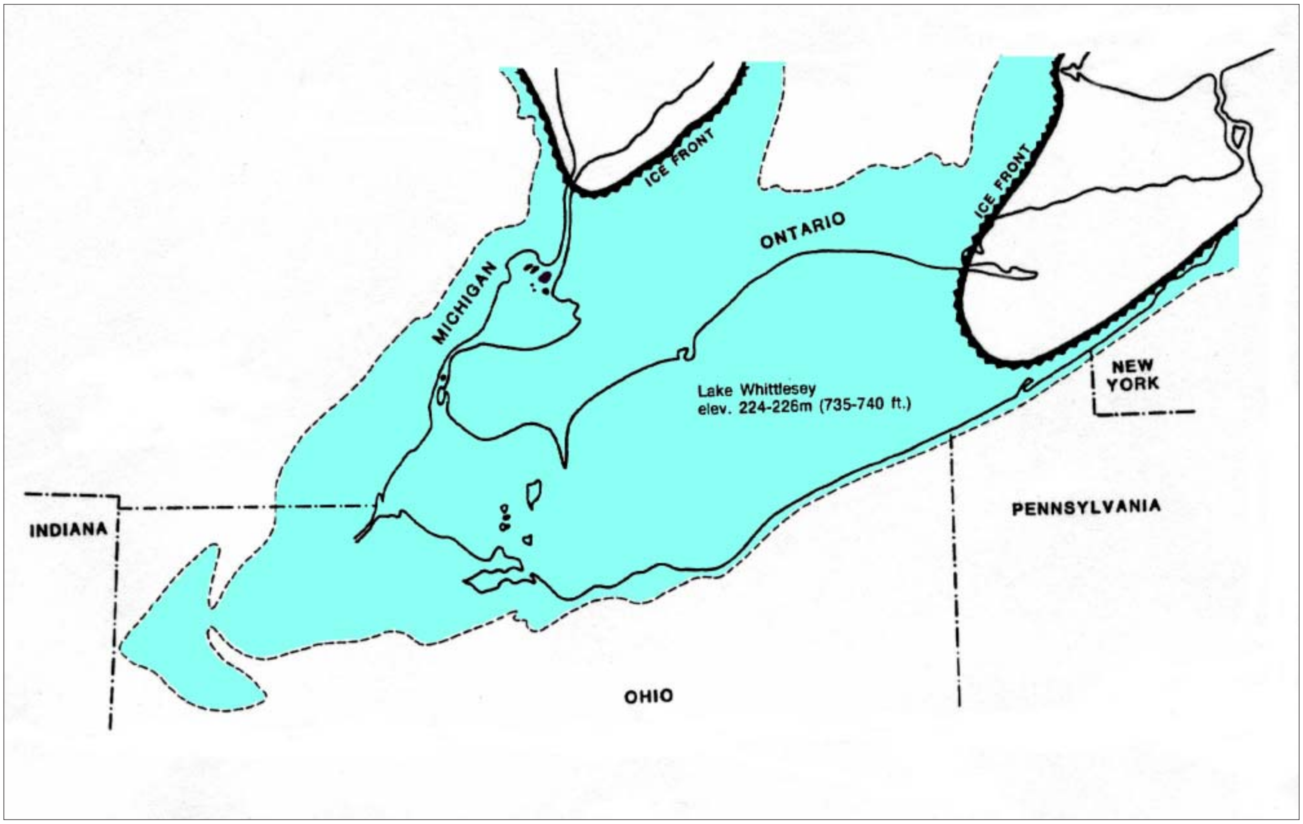


Figure 2.48. Glacial Lake Whittlesey (from Herdendorf 1989).

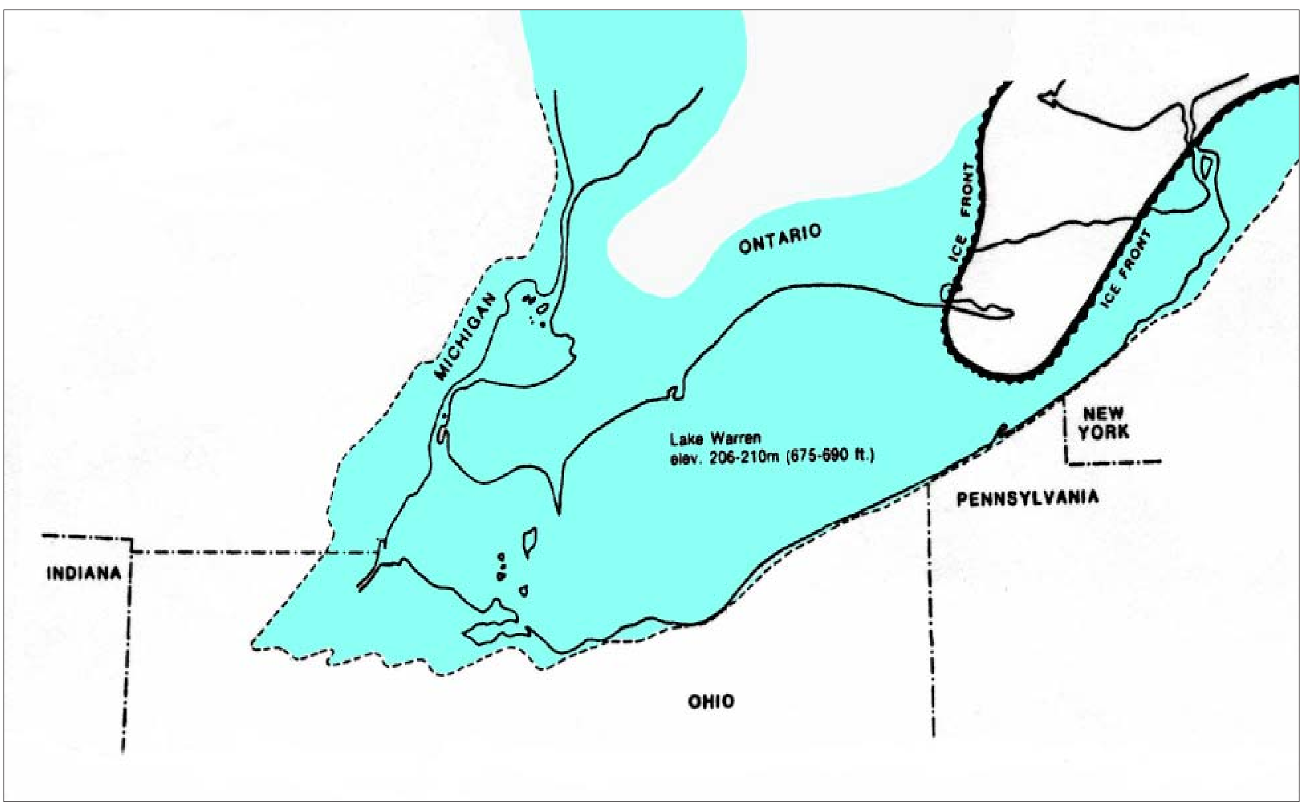


Figure 2.49. Glacial Lake Warren (from Herdendorf 1989).

In the vicinity of Old Woman Creek, the highest Lake Warren stage (I) is well represented by wave-cut cliffs starting at the west branch of the creek north of Berlinville and extending northeast to the valley of Chappel Creek. The cliffs are cut into the Ohio Shale at the base of the Berea Escarpment at an elevation of 210 m (690 ft). The only beach ridges mapped in the watershed at this elevation are north of Berlinville, immediately south of the cliffs, where they are backed by sand dunes. West of the west branch of the creek, the lower Lake Warren stages (II and III) are marked by beach ridges and abundant sand dunes at elevations ranging from 204 to 207 m (670 to 680 ft). Some of the more southerly of these dunes are at a higher elevation and may have been formed during the highest Lake Warren stage. To the northeast, the only mapped features of the lower Lake Warren stages are low beach ridges at the 204-m (670-ft) elevation between Frailey Road and Joppa Road in Vermilion Township. The only Lake Wayne features in eastern Erie County are also located in the same area – low, arcuate beach ridges at an elevation of 201 m (660 ft).

GLACIAL LAKES GRASSMERE AND LUNDY (12,500–12,400 YBP)

Renewed retreat of the ice margin from its position during the lowest stage of Lake Warren caused the water level to drop to an elevation of 195 m (640 ft), creating Lake Grassmere. This drop in lake level resulted in the final abandonment of the Grand River valley in Michigan as an outlet for lakes in the Huron and Erie basins (Eschman and Karrow 1985). Further retreat of the ice in the Huron basin dropped the lake elevation to 189 m (620 ft) and initiated a stage known as Lake Lundy. These stages were short-lived and are marked by weak and discontinuous shore features in the Huron and Erie basins. Neither the direction of drainage nor the outlet channels of Lake Grassmere and Lake Lundy have been determined with certainty (Calkin and Feenstra 1985). Some investigators believe that drainage continued to the west during these stages; while others contend an eastward outlet. In addition to the filling the Erie basin, Lake Grassmere and Lake Lundy also occupied much of the southern half of the Huron basin. Both lakes had surface areas of approximately 75,000 km^2 (Prest 1970).

In the Old Woman Creek watershed, evidence of the Lake Grassmere and Lake Lundy shorelines have only been found in the vicinity of Shinrock. To the south of this community, at an elevation of 195 m (640 ft), low beach ridges have been mapped between the two main branches of Old Woman Creek. North of this community, at an elevation of 187 to 189 m (615 to 620 ft), three low sandy ridges have been identified that run east-west between the Huron River valley and Old Woman Creek. The drop in water level from glacial Lake Lundy to nonglacial Early Lake Erie may have been marked by brief pauses that in turn are represented by weak and intermittant shore features. Calkin and Feenstra (1985) postulated that two Early Lake Algonquin stages (Huron basin), at elevations of 184 m (605 ft) and 180 m (590 ft), extended into the Erie basin. Low, sandy ridges at the lower elevation have been observed by the authors on the west side of the Old Woman Creek estuary, within 1 km of the present Lake Erie shoreline. These features may represent an Algonquin stage; or, alternatively, higher, modern Lake Erie levels (3,000 to 1,000 YBP) as postulated by Barnett (1985) and Coakley and Lewis (1985).

EARLY LAKE ERIE (12,400–8,000 YBP)

The glacial lake stages in the Erie basin ended when the ice margin reteated sufficiently into the Ontario basin to allow water in that basin to fall below the Niagara Escarpment. This removed the direct glacial influence in the Erie basin and initiated the present lake. Forsyth (1973) described a catastrophic flood of water over the escarpment that incised a channel in the moraines and bedrock, resulting in a low water stage in the Erie basin. The Niagara threshold, still depressed by glacial loading, was 25 to 30 m below the present Lake Erie level (Hartley 1958, Coakley and Lewis 1985). Hartley (1958) presented a compelling argument for a low stage at 25 m below the current level based on field evidence, while Coakley and Lewis (1985) used radiocarbon dates and contours on the glacial till surface to show a minimum level at least 30 m below the present lake level. Known as Early Lake Erie, this low stage had an elevation of 149 m (490 ft) or lower and a surface area of approximately 11,200 km^2 (Figure 2.50). The evolution of Lake Erie from this low water stage to its present level involves glacio-isostatic rebound, changes in discharge waters to the lake, and climatic fluctuations (see Climatology Chapter for discussion of air temperature trends during glacial and postglacial periods).

Initially, Early Lake Erie received discharge from Early Lake Algonquin (Huron basin) via the newly formed St. Clair River-Lake St. Clair-Detroit River system (Calkin and Feenstra 1985). Early Lake Erie may have consisted of: (1) a marshy western basin through which an extention of this river system flowed via Pelee Passage (Hobson et al. 1969, Herdendorf and Braidech 1972), (2) a shallow central basin lake that flowed to the east via a channel cut through the Norfolk moraine, and (3) a deeper eastern basin lake which drained to the east over the Niagara Escarpment. Differential glacio-isostatic uplift of the Niagara River outlet was rapid from about 12,400 to 11,400 YBP, over 2.0 m/century, followed by a slowing of the uplift rate to less than 1.0 m/century from 9,000 to 8,000 YBP (Figure 2.43) (Lewis 1969, Coakley and Lewis 1985). Early in this period, about 12,000 YBP, flow into the western basin was interrupted when the Kirkfield outlet (Figure 2.40) for Lake Algonquin (Huron basin) was opened to Lake Iroquois (Ontario basin) by deglaciation, lowering the level in the Huron basin and stopping drainage to Early Lake Erie (Kaszycki 1985). For the next 7,000 years drainage from the upper lakes bypassed Lake Erie. Isostatic uplift continued to raise the level water in the Erie basin, but cessation of over 90% of the lake's former inflow must have created stagnant and perhaps eutrophic conditions. In fact, Lewis et al. (1999b) concluded that the lake was a closed basin.

Following Lake Algonquin, the upper Great Lakes went through a series of successively lower stages until the North Bay-Ottawa River outlet was opened to the St. Lawrence embayment of the Atlantic Ocean (Figure 2.40). The lowest stages were Lake Chippewa (Michigan basin) and Lake Stanley (Huron basin). For at least 5,000 years the level in the Michigan and Huron basins was controlled by uplift of the Ottawa River outlet (Prest 1970). This period of gradually rising levels lasted until the Lake Nipissing stage (Huron basin) when water was again transferred to the Erie basin via the St. Clair - Detroit River system.

At the beginning of the low water stage the shoreline of Early Lake Erie was at least 65 km east northeast of the present Old Woman Creek estuary. During this stage, Old Woman Creek excavated a 15-m deep channel through lacustrine sediments (deposited during the higher lake stages) and in glacial till (deposited in the 44-m deep preglacial Huron River valley) (Herdendorf and Hume 1991). The depth of the channel is considerably greater than would be expected under the current stream environment and is likely the result of the lower base level of the stream during the low stage which accelerated its erosion capabilities (Buchanan 1982).

MIDDLE LAKE ERIE (8,000–4,000 YBP)

After 10,000 YBP the rising water in the Erie basin slowed and at 8,000 YBP it leveled off at an elevation between 157 to 163 m (515 to 535 ft), remaining there for about 4,000 years (Figure 2.43). Hartley (1958) called this intermediate stage Middle Lake Erie. Forsyth (1973) explains this stable-level period as a possible reponse to decreased precipitation and increased evaporation during the Xerothermic or Hypsithermal Interval (Sears 1942, Phillips 1989) which counter-balanced the isostatic uplift. Near the close of this stage, between 5,000 to 4,000 YBP, drainage from the upper lakes returned to Lake Erie as a result of continued glacial uplift around North Bay, Ontario. This ended upper lakes drainage to the Ontario basin and created the Lake Nipissing stages in the Huron basin (Lewis 1969, Calkin and Feenstra 1985). This event (a major new inflx of water from the upper lakes), plus more humid climatic conditions, may have sharply increased water levels in Lake Erie and given impetus to the formation of a large delta (Figure 2.51) in western Lake Erie at the mouth of the ancestral Detroit River (Herdendorf and Bailey 1989). Deposition of a massive delta in Lake St. Clair is also believed to have taken place at this time (5,000 to 3,500 YBP). Radiocarbon dates for lacustrine clays (7,300 YBP) underlying the pre-modern St. Clair River delta show that formation of the delta began during Lake Nipissing time (Raphael and Jaworski 1982, Kaszycki 1985) and not during Lake Algonquin time (12,400 to 10,600 YBP) as ascribed by earlier investigators (Flint 1957). Coakley et al. (1999) also found evidence of a "Nipissing flood" in borehole data from Point Pelee.

A radiocarbon date of 7,690+210 YBP was obtained from sediment deposited about 6 m (20 ft) below the present level of Old Woman Creek estuary (Buchanan 1982). Based on radiocarbon dates from the western basin of Lake Erie (Lewis 1969, Herdendorf and Braidech 1972, Sly and Lewis 1972), Middle Lake Erie was at an elevation of about 159 m (522 ft) at this time or 15 m (49 ft) below the present

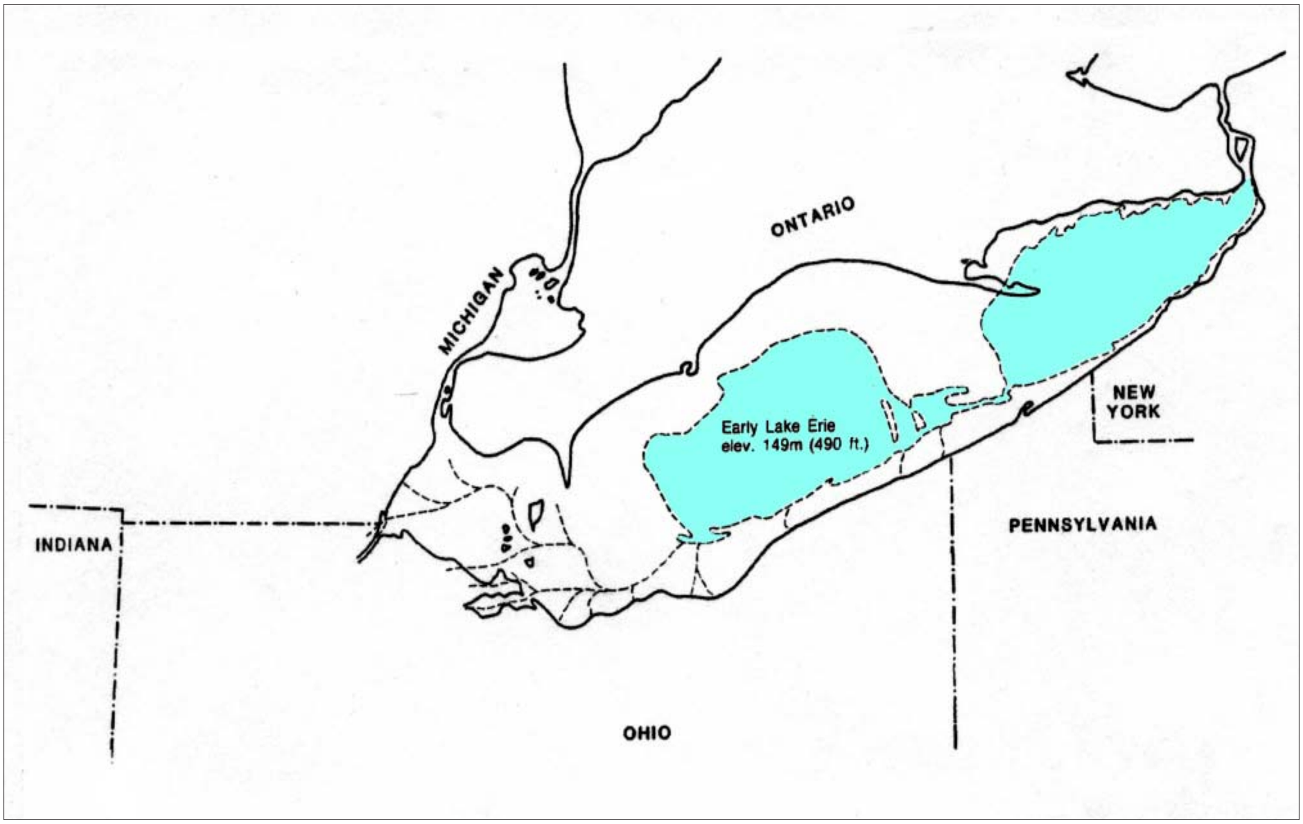


Figure 2.50. Early Lake Erie, circa 10,000 YBP (from Hartley 1958, Herdendorf 1989).

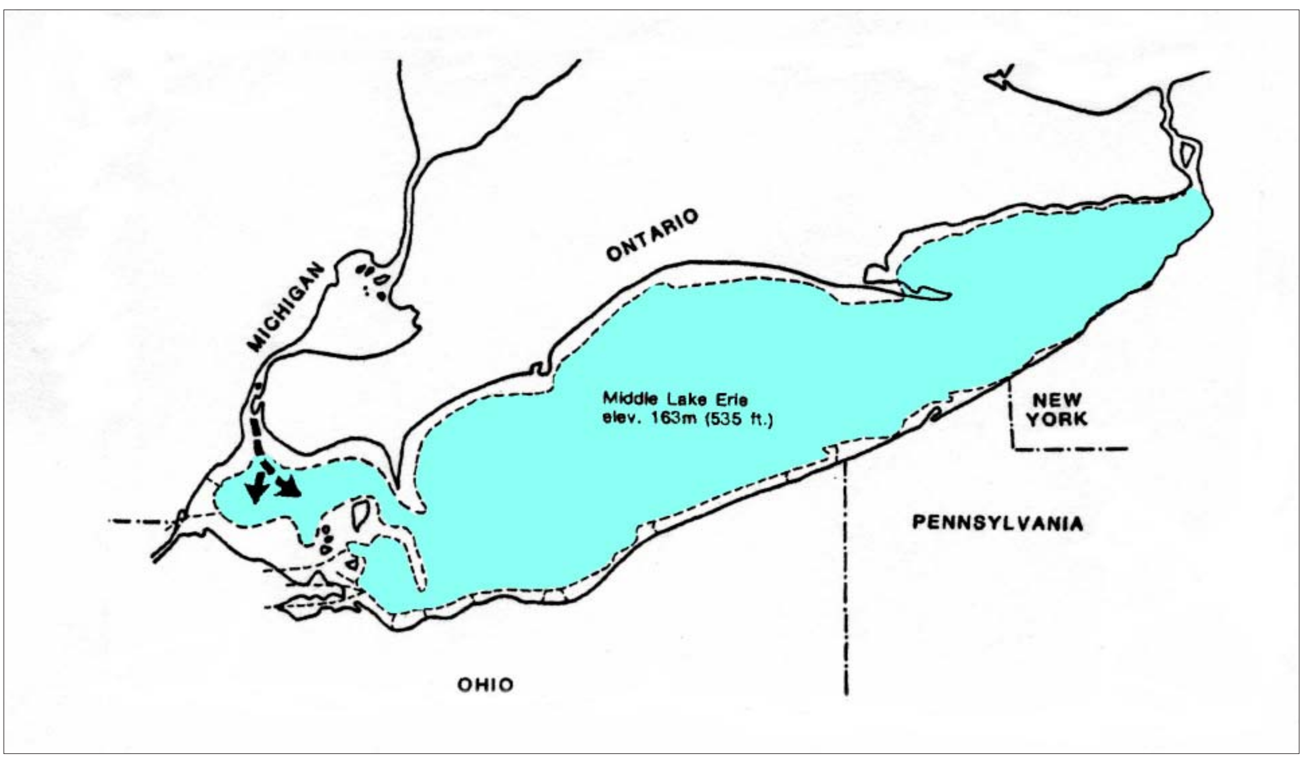


Figure 2.51. Middle Lake Erie, circa 4,000 YBP, at inception of ancestral Detroit River delta (from Herdendorf and Bailey 1989).

level of the Lake Erie. Thus, at about 7,700 YBP, the site of the present estuary was merely a point along a stream channel some 7 km inland (southwest) of the lakeshore. Because the erosion base level was 15 m lower than present, Buchanan (1982) calculated a 2.3 m/km gradient for the stream, nearly twice the present gradient of the lower course of Old Woman Creek. The steeper gradient would have generated stream velocities of 1 to 13 m/sec, permitting the stream to transport coarser material to the site of the future estuary than that which is presently being deposited there. As the lake level rose, the shoreline transgressed toward the south, reducing the gradient so that finer and finer sediments were deposited at the site. This assumption is supported by the textural gradation observed in the core, from sandy sediment at the bottom of the core, through a sandy silt portion, to predominantly silty clay material in the upper two-thirds of the core.

MODERN LAKE ERIE (4,000 YBP– PRESENT)

As Lake Erie rose to its approximate current level (Figure 2.1), 174 m (570 ft), about 4,000 to 3,500 YBP, the south shore tributary channels which were deeply incised into lacustine sediment and glacial till during the low water stage of Early Lake Erie, were flooded by lake encroachment, creating estuarine-type mouths (Herdendorf 1990, Holcombe et al. 2003). In Ohio alone, 42 km^2 of estuary waters were formed at the mouths of 18 tributaries for a total linear distance of 160 km (Brant and Herdendorf 1972). As coastal erosion proceeded and beach-building sand was delivered to the littoral zone, massive sand spits were built at Point Pelee and Long Point in Ontario, at Presque Isle in Pennsylvania, at Woodtick Peninsula in Michigan, and at Cedar Point and Bay Point in Ohio. At the same time, barrier beaches and bars were formed across the mouths of most of the estuarine tributaries. The barriers served to control water levels, influence sediment deposition, and enhance wetlands development within the estuaries.

Both the rise in lake level and the deposition of material within the Old Woman Creek channel served to reduce the stream gradient and water velocities. As a result, finer and finer sand and silt were deposited until about 4,000 YBP. Since that time only fine silts and clays have been transported into the estuary (Buchanan 1982). Additional pollen analysis and radiocarbon dating (4,220+20 YBP) of peat in a sediment core at 2 m (7 ft) below the present level of Old Woman Creek, elevation 172 m (564 ft) by Reeder and Eisner (1994) indicate that water levels have remained at depths sufficient to support the growth of shallow water vegetation for at least the past 4,000 years. These researches noted that even under heavy sediment loading and moderate water level fluctuations (1 to 3 m), the estuary remained a wetland and did not fill in, suggesting that the barrier bar at the mouth of the estuary facilitates a hydraulic equalibrium, whereby excess sediment is flushed out of the estuary.

Lake Erie waters have now reached a near-stable level, although minor crustal warping appears to have continued to the present (Calkin and Feenstra 1985). A study by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (1977) showed the maximum relative deformation rate for all measured sites in the Erie basin is less than 64 mm/century. The study report concluded that present crustal movement rates for Lake Erie are minimal between the inlet and outlet of the lake, consequently there is little effect on mean lake level with time.

SURFICIAL GEOLOGY AND SEDIMENTOLOGY

GLACIAL DEPOSITS

Approximately one million years ago, great ice sheets began to move southward and westward out of Canada and into the Erie basin. Several glacial lobes, some as much as 2 km thick, moved up pre-glacial river valleys. One of these, the Erigan River valley, ran in a general northeast direction up the basin now occupied by modern Lake Erie (Spencer 1891). The scouring action of the glacier enlarged the valley, forming a broader and deeper Erie basin (Bolsenga and Herdendorf 1993). During and after the retreat of the last glacier, up to 35 m (115 ft) of glacial till and 76 m (250 ft) of sediment have been deposited in the glaciated valley (Wall 1968) to give modern Lake Erie a much smoother and flatter bottom than it had when water first filled the basin.

As the Pleistocene glaciers followed the ancient streams into Ohio, the valleys were scoured deeper and the meanders were smoothed. The resistant bedrock that underlies Erie and Huron counties was not deeply cut by glacial ice, but profound erosion features are evident in the area, such as the spectacular glacial grooves in the Columbus Limestone on Kelleys Island and the massive overturned slabs of Berea Sandstone in the Chappel Creek valley, Florence Township (Figure 2.31). As the ice sheets moved over the land a sheet of rock debris, or ground moraine, was deposited. When the glaciers paused in their advance or retreat, ridges known as end moraines were built up of rock debris at the ice margins. The debris, referred to as glacial till, is composed of a heterogeneous mixture of rock fragments ranging in size from clay to boulders. In places, end moraines were deposited in such a way as to dam the natural drainage and thereby form large lakes in the scoured depressions.

Nearly all unconsolidated material overlying the bedrock in the vicinity of Berlin Heights and the Old Woman Creek drainage basin is glacial in origin, deposited either directly by the Wisconsinan ice sheet or in glacial lakes that were predecessors of Lake Erie (Figure 2.52). Gently rolling ground moraine, late Wisconsinan in age (Campbell, 1955), covers the southern portion of the Old Woman Creek drainage basin to an average depth of 8 m (25 ft). Notable exceptions are hills of Berea Sandstone, which have little or no till cover, and, at the estuary mouth where a buried valley is filled with 44 m (147 ft) of glacial drift and lake sediments (Buchanan 1982). South of the present shoreline, beach deposits of six glacial lake stages have been recognized: Lake Maumee, Lake Whittlesey, Lake Arkona, Lake Warren, Lake Wayne, and Lake Lundy, from highest to lowest. Glaciolacustrine deposits formed in these lakes are thin and discontinuous except in the vicinity of the beach ridges, and are best exposed in the present lake bluffs (Figure 2.53). Widely scattered lagoonal deposits are present in the beach ridge area and in places contain minor deposits of peat and bog ores.

Figure 2.52. Lake Erie shore bluff at Vermilion, Ohio showing pebble-rich glacial till clay overlying Ohio Shale (Charles E. Herdendorf).

Figure 2.53. Lake Erie shore bluff east of Old Woman Creek showing glaciolacustrine deposits (Charles E. Herdendorf).

Huron River Embayment

Immediately west of the Berea Escarpment in southeastern Erie County, a sharp southerly indentation is present in all of the abandoned shorelines of the glacial lake stages (Figure 2.18). The Huron River entered the lakes through this bay and was the primary factor in controlling sedimentation in the area. Carney (1911) applied the name "Huron River embayment" to this area which encompassed the northern part of Old Woman Creek watershed and extended westward to the base of Cedar Point and southward to Norwalk. Campbell (1955) referred to the body of water within this area at the various lake stages as "Huron Bay."

The bedrock of the embayment comprises an area of lower elevation, carved out of shale, when compared to the higher elevations of the more resistant sandstone of the escarpment to the east and the limestone terrain to the west. While the bay existed, the limestone terrain formed either a northeasterly trending peninsula or a

Figure 2.54. Lake Erie shore bluff west of Cranbery Creek showing laminated lacustrine deposits (Charles E. Herdendorf).

string of islands. Likewise, the eastern edge of the embayment was controlled by the position of the Berea Escarpment and exhibits wave-cut features.

GLACIOLACUSTRINE DEPOSITS

Sediments deposited in the glacial lakes comprise the Lake Erie bluffs from Cranberry Creek west to Huron (Figure 2.54). These glaciolacustine deposits consist largely of interlaminated clay and silt; the clay laminations are dark brown and the silt layers are light brown on weathered surfaces. The mineralogy of the clay is illite with minor amounts of chlorite (Carter and Guy 1980). Near the contact with the underlying till, the clay and silt laminations are poorly defined and there is typically a zone of deformed clay and silt.

The glaciolacustrine deposits that comprise the lake bluff at Ceylon Junction, 1.4 km east of Old Woman Creek estuary, were studied by Goodman (1956) and found to consist of sand (1.6%), silt (68.2 %), and clay (30.2%). When fresh these lake deposits are typically bluish gray, but exposed surfaces have brownish-gray and yellow-brown mottles caused by oxidation and staining. Exposures in the Lake Erie bluffs in the vicinity of the estuary indicate that the ancient lake deposits constitute only the upper 6 m (20 ft) of the sediment. These beds show distinct interlaminations of silt and clay. Contorted stratification occurs in the lower 3 m of the lacustrine beds at Oberlin Beach (Figure 2.55). This disturbed stratification has been attributed to pene-contemporaneous slumping or distortion caused by ice flows associated with a minor ice advance or reworking by wave action (Campbell 1955, Herdendorf 1963b).

Varves

The bluffs of Old Woman Creek estuary, particularly those on the east side of the estuary immediately south of the U.S. Route 6 bridge (Figure 2.56), and the Lake Erie bluffs fronting Oberlin Beach to the east of the estuary mouth exhibit glaciolacustrine varves. These sedimentary beds are composed of a sequence of laminae deposited in a glacial lake in a year's time. Each varve consists of a thin pair of graded glaciolacustrine layers seasonally deposited by meltwater streams in a glacial lake which existed in front of the glacier (Figure 2.57). The glacial varves at Old Woman Creek include a lower "summer" layer, composed of relatively coarse-grained, light-colored silt and very fine sand produced by rapid melting of ice in the warm months, which grades upward into a thinner "winter" layer, consisting of very fine-grained clayey sediment, often organic and dark-colored,

Figure 2.55. Lake Erie shore bluff at Oberlin Beach, adjacent to Old Woman Creek mouth showing contorted lacustrine beds resulting from ice action during a glacial lake stage; varved bedding exhibited in upper layers (Charles E. Herdendorf).

Figure 2.56. East bluff of Old Woman Creek estuary exhibiting varves in lacustrine sediments (Charles E. Herdendorf).

Figure 2.57. Close-up view, same location as Figure 2.56, showing structure of varves (Charles E. Herdendorf).

slowly deposited from suspension in quiet water while the streams were ice-bound. A sedimentary feature that is characterized by the repetition of a pair of unlike laminae showing a gradation in grain size from coarse below to fine above is said to possess diatactic structure (Bates and Jackson 1980). Campbell (1955) measured interlaminated lacustrine deposits west of the Huron River that averaged 8 mm per couplet, but she was uncertain if they represented true glacial varves because diatactic structure could not be demonstrated. However, the interlaminated silts and clays at the estuary appear to have been deposited in the higher glacial lakes stages from Lake Maumee to Lake Lundy.

Counting the number of couplets can provide a measure of the time sequence represented by a particular deposit. For example, varve couplets measured by the authors near the mouth of Old Woman Creek estuary average 10.3 mm in thickness. The maximum height of the varved deposits ranges from 6.1 m (20 ft) on the lakeshore to 3.7 m (12 ft) in the estuary. Hence, the bluffs near the mouth of the estuary represent a depositional period of nearly 600 years or about 36% of total time that higher glacial lakes covered the estuary site.

POSTGLACIAL AND MODERN SEDIMENTS

Stream Deposits

The oldest alluvial sediments were deposited within the channel of Old Woman Creek and on the narrow floodplain across which the channel migrated about 8,000 YBP. These sediments exist 6 m below the current estuary floor and consist of coarse to fine sands and silts deposited in the more swiftly flowing channel of the creek when the level of Lake Erie was much lower and the stream possessed a higher gradient. As the lake rose, the stream gradient of Old Woman Creek was reduced and the site of the estuary experienced increasing amounts of sediment deposition involving finer and finer sediments. As deposition progressed and the floor of the estuary rose in elevation, the size of the area over which the creek channel migrated increased, eventually to encompass and laterally enlarge the deep valley cut in the underlying lacustrine sediments and till by the early, erosive channel of the creek. Currently, only silts and clays are transported into and deposited in the estuary of Old Woman Creek (Buchanan 1982).

Estuary Deposits

Within the last 100 years, the combined effects of rising lake levels and sediment deposition may have decreased the water depth in the estuary to such a degree that shallow-water aquatic vegetation has begun to colonize its floor (Buchanan 1982). The first indication of this colonization are zones of dark, organic-rich sediments with plant debris in the upper 1 m of cores recovered from the estuary. Using recent lake-level records and aerial photographs, Buchanan estimates that shallow water depths, between 15 to 30 cm, are necessary for such vegetation to flourish and that conditions such as these were present in the estuary between the 1920s and 1960s. A more recent core (Reeder 1989) reveals deeper, organic-rich layers which may indicate even earlier low-water/high productivity periods in the estuary. Using Buchanan's radiocarbon data, the sediment depositional rate in the estuary over the last 8,000 years has averaged 0.70 mm per year. Most likely this rate has been greatly accelerated in the last 100 years due to agricultural development within the drainage basin. Current depositional rates in the estuary are estimated by Buchanan to be 10 mm per year.

Matisoff et al. (1998) demonstrated that the type of soil tillage has an influence on the erosion rate in Old Woman Creek watershed and the ultimate delivery of sediment to the estuary. They selected several drainage sub-basins for study where agricultural management included either tilled or no-till practices. By using a radioactive isotope of beryllium as a tracer, they were able to track soil erosion losses for each sub-basin for a single rainstorm event in 1996. The results of the study showed the advantages of no-till practice in controlling soils loss.

Practice	Mean Sub-basin	Erosion Rate
Tilled	2.17 km^2	7.1 tonnes/km^2
No-till	2.17 km^2	0.8 tonnes/km^2

Because most of Lake Erie's undisturbed estuary inlets are barred across a significant portion of the year, it has been postulated that the presence of such barriers control, to a large part, sediment infilling within the estuary. Buchanan (1982) noted that recent depositional rates in Old Woman Creek estuary may range as high as 1 cm/yr in response to increased agricultural activity upstream and the damming effect of the barrier bar at the estuary mouth. He also concluded that colonization of the estuary floor by aquatic plants has only become possible in that period of time represented by the upper meter of sediment (100 years assuming a sedimentation rate of 1 cm/yr), because water depth appears to be the dominant control for plant abundance.

More recent findings show a quite different picture. Water levels in Lake Erie have varied considerably in the past 12,000 years, falling from 247 m to 146 m then up 174 m above sea level due to isostatic adjustment following deglaciation. Approximately 4,000 to 5,000 YBP the lake stabilized near its present level and has fluctuated only a few meters up and down since. Once the lake stabilized, barrier bars were deposited across the drowned mouths of most of the tributaries, forming what is now referred to as freshwater estuaries. Sediment cores (Reeder 1989) indicates that peat layers composed of aquatic plant material extend for several meters below the estuary floor and yield radiocarbon dates of 4,000 to 5,000 YBP. Apparently colonization by aquatic plants is not a new feature of the estuary, but there must have been some mechanism operating through time to control water level at depths optimal for plant growth.

Sediment Chemistry

The chemistry of the sediments and the interactions between the sediments and the overlying waters in Old Woman Creek estuary have received attention by the scientific community. Frizado et al. (1986) studied the mineralogy of the sediment in the Old Woman Creek estuary and determined that its probable sources were (1) glacial till, lacustrine sediment, and soils and (2) Berea Sandstone in approximately equal parts. However, they believed that the sediment load of the Berea Sandstone was probably overestimated due to the export of fine grained particles from the tills, sediments, and soils out of the estuary. Frizado et al. (1986) and Mancuso (1986) measured the concentration of selected metals in the interstitial waters and determined that the chemistry of these waters is not related to the bulk mineralogy of the sediments. However, the concentrations of many of the trace metals were higher in this interstitial water than in the overlying waters. This suggested that these waters may serve as a source of trace metals to the estuary. Matisoff and Eaker (1989, 1992) measured or calculated three different fluxes—direct solute flux across the sediment water interface, diffusional fluxes calculated pore water chemical concentrations, and seepage fluxes from groundwater. In the estuary they concluded that diffusional fluxes were insignificant to seepage fluxes and these were in turn insignificant to the direct fluxes. These fluxes between the sediments and the overlying waters are significantly impacted by activities of the benthic fauna. Pfister and Frea (1989) examined the movement of cadmium from the overlying waters into the sediments. They determined that bacteria enhanced this downward movement.

Buchanan (1982) examined the percentage of organic content in a sediment core from Old Woman Creek estuary. The abrupt increase in organic content at approximately 150 cm below surface was interpreted as a change in water levels in the estuary (and in the lake) that would make the estuary suitable for in situ macrophytic growth. Prior to this period, Buchanan considered any organic matter in the sediments as being transported from the terrestrial watershed. He supports his hypothesis by noting that the sediments above this zone contain matted rootlets and other remains of plant material, while those below do not contain such material. Buchanan (1982) also reported thin bands of largely inorganic silty-clays between the high organic layers in the upper 150 cm of the core. He believed that these thin layers of low organic content represented periods when lake levels were too high to permit the growth of aquatic macrophytes in the estuary.

Beach Deposits

Old Woman Creek does not enter Lake Erie in the typical way—it must first pass through the barrier beach. At times the barrier is opened by a channel which leads to the lake (Figure 2.58), but often it is closed by sand bars (Figure 2.59). When the estuary mouth is completely sealed off by the barrier beach, the creek waters must percolate through the sand to find their way to the lake. Wind storms over the lake and rainstorms over the watershed can produce the forces necessary to breach the barrier and allow Old Woman Creek to flow freely to the lake. Once these violent events have subsided however, the shifting sands of the coast can quickly close the channel and the estuary is again isolated from the open lake. The barrier is critical to the protection and maintenance of coastal wetlands. By separating estuary from the lake, fragile aquatic plants are protected from wave attack. The beach allows the waves to break and roll up a gentle slope, dissipating energy and reducing the waters ability to erode the shoreline and undermine vegetation.

At the mouth of Old Woman Creek, the barrier beach is composed of medium- to coarse-grained sand (Figure 2.60). Quartz dominates these grains, but patches of reddish-purple garnet and black magnetite are common (Figures 2.61 and 2.62). These three materials are typically arranged in density layer, with the heavier magnetite lowest on the beach, followed by garnet, then quartz. Waves carrying the grains of sand onto the beach are effective in sorting these minerals by their specific gravity (Herdendorf 1963b). The beach sand has a maximum thickness of 7 m and overlies glacial till that is exposed at the shoreline east of the barrier beach.

Figure 2.58. Barrier beach at Old Woman Creek estuary mouth showing an open channel (Charles E. Herdendorf).

Figure 2.59. Barrier beach at Old Woman Creek estuary mouth showing a closed channel (David M. Klarer).

Figure 2.60. Layered beach sand in the barrier bar at the mouth of Old Woman Creek estuary (Charles E. Herdendorf).

Figure 2.61. Patches of reddish-purple garnet and black magnetite grains on the predominately quartz sand beach at the mouth of Old Woman Creek estuary (Charles E. Herdendorf).

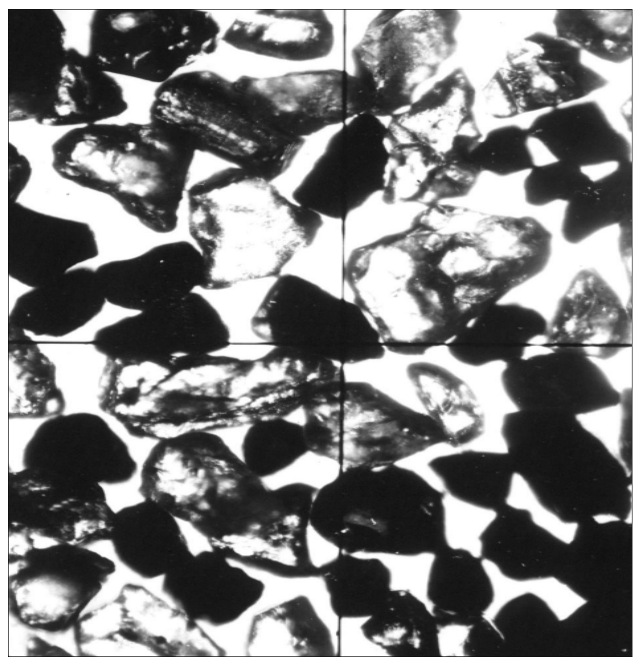


Figure 2.62. Photomicrograph of angular garnet (light) and magnetite (dark) beach sand grains from the Old Woman Creek barrier beach (Charles E. Herdendorf).

Soils formed on abandoned Lake Warren beach ridge (Charles E. Herdendorf).

Chapter 3. Soil Science

Pedology, one of the disciplines of soil science, includes the study of soil morphology, properties, genesis, and classification. Agronomy is another branch of soil science that deals with soil management and crop-producing characteristics. Both of these aspects of soil science are important in understanding the natural setting and land use patterns in Old Woman Creek watershed as well as the impact of soils on the ecology of the estuary. Soil surveys of the watershed have been included in surveys of Erie County (Redmond et al. 1971, Martin and Prebonick 1994) and Huron County (Ernst and Martin 1994). In addition, a survey of adjacent Lorain County (Ernst et al. 1976) provides further insight to soil characteristics of the region.

Soil Maps

The soils in the watershed occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil is associated with a particular landscape or segment of the landscape. The soil surveys referenced above were used to compile a soil map of Old Woman Creek watershed plotted on aerial photographs (Figure 3.1; see Table 3.1 for soil names). For mapping purposes, soils were classified or grouped together if they have similar profile horizons. A total of 67 different kinds of soils have been mapped in the 7,032 hectares that comprise the Old Woman Creek watershed (Table 3.1). Of these, only 10 soil types account for nearly 60% of the watershed area (see below).

Top 10 Soils of Old Woman Creek Watershed

	Hectares	Watershed
Bennington silt loam (BgA)	1,306	18.6%
Cardington silt loam (CaB)	413	5.9%
Haskins loam (HkA)	349	5.0%
Condit silt loam (Co)	328	4.7%
Bennington silt loam (BgB)	327	4.7%
Mermill silty clay loam (Me)	315	4.5%
Elnora loamy fine sand (EnA)	312	4.4%
Bixler loamy fine sand (BkA)	295	4.2%
Kibbie fine sandy loam (KbA)	265	3.8%
Holly silt loam (Ho)	263	3.7%
TOTAL	4,173	59.5%

Soil Formation

Factors that determine the kinds of soils that formed in the Old Woman Creek watershed are (1) composition of the parent material, (2) climate under which the soil material accumulated or weathered, (3) relief of the terrain, (4) plants and animals on and in the soil, and (5) length of time the forces of soil development have acted on the soil material (Jenny 1941). The variety of soils found in the watershed resulted from variations in one or more of these factors (Redmond et al. 1971).

Parent Material

The underlying material is a dominant factor in the formation of most of the watershed soils, largely determining the chemical nature and mineral composition of the soil. Parent materials in the watershed are sedimentary bedrock, glacial till, glacial outwash, ancient lake deposits, recent stream alluvium, and organic material (Figure 3.2). The various types of parent material in the watershed are associated with specific soils as shown, generally from oldest to youngest material, on the following page.

The watershed was covered by glaciers during the Pleistocene epoch. Thus, glacial till is the major parent material of the soils. Bennington, Cardington, and Condit are examples of soils that formed in glacial till (Figure 3.3). Beach ridges and deltas formed along the edges of a series of glacial lakes. Elnora, Oshtemo, and Spinks are examples of soils that formed in these deposits. Outwash of silt, sand, and gravel was deposited by meltwater along glacial streams. Chili and Jimtown soils formed in glacial outwash. Lacustrine material consisting of loamy to clayey sediment was deposited in glacial lakes in the northern part of the watershed. Kibbie, Shinrock, and Tuscola soils formed in lake and outwash deposits (Figure 3.4).

Climate

Old Woman Creek watershed has a humid, temperate continental climate (see Climatology chapter of this profile). Soils in the watershed formed under the influence of this type of climate. Important climatic factors such as temperature, precipitation, and the evaporation ratio are closely related to the biotic

SEE MAP TO RIGHT

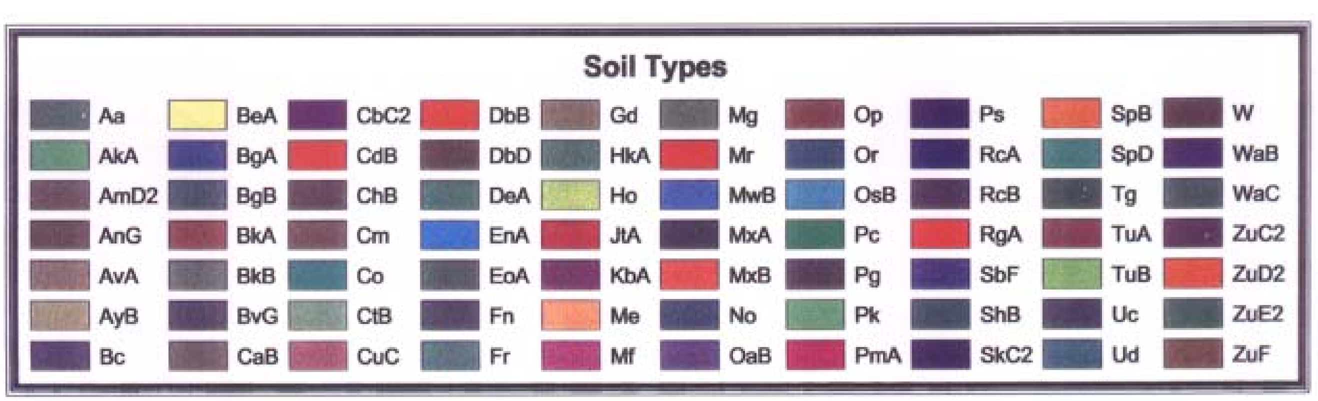
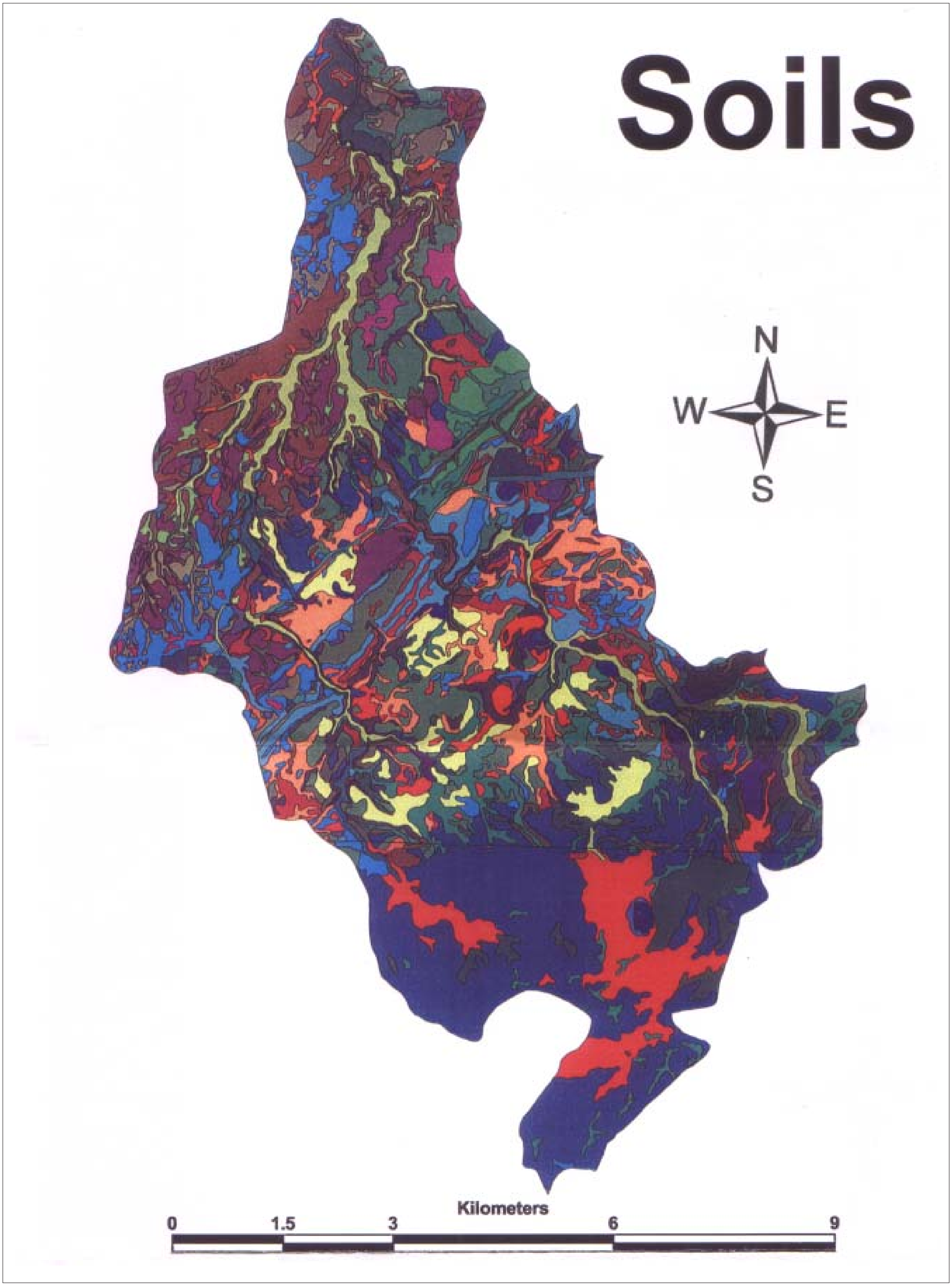


Figure 3.1. Fold-out soil map of Old Woman Creek watershed, Erie and Huron Counties, Ohio; Tables 3.1 through 3.4 contain explanations of map symbols, characteristics, properties, limitations, and erodibility of Old Woman Creek watershed soils (Ohio Department of Natural Resources).


Soils
N
W
E
S
Kilometers
0
1.5
3
6
9

PARENT MATERIALS FOR OLD WOMAN CREEK WATERSHED SOILS

Bedrock controlled knolls & side slopes
- Amanda-Dekalb rock outcrop assoc. (An) —residuum
- Brecksville silt loam (Bv)
- Dekalb channery loam (Db)

Bedrock controlled Till Plains & Lake Plains
- Allis silty clay loam (Ak)
- Fries silty clay loam (Fr)
- Mitiwanga silt loam (Mx)

Bedrock controlled Outwash Plains & Beach Ridges
- Wakeman sandy loam (Wa)

Till Plains
- Amanda loam (Am)—side slopes
- Cardington silt loam (Ca) & silty clay loam (Cb)
- Condit silt loam (Co)

Till Plains & Outwash Plains
- Haskins loam (Hk)
- Rawson sandy loam (Rc)
- Rimer loamy fine sand (Rg)

Outwash Plains
- Millgrove loam (Mg)

Outwash Plains & Beach Ridges
- Oshtemo loamy sand (Os)
- Spinks loamy fine sand (Sp)

Till Plains & Lake Plains
- Bennington loam (Be) & silt loam (Bg)
- Gilford fine sandy loam (Gd)
- Mermill silty clay loam (Me)
- Miner silty clay loam (Mr)
- Pewamo silty clay loam (Pc)
- Rawson sandy loam (Rc)
- Rimer loamy fine sand (Rg)

Lake Plains & Outwash Plains
- Adrian muck (Aa)—former bogs
- Kibbie fine loamy sand (Kb)
- Ogontz (Avery) fine sandy loam (Og or Av) & silt loam (Oh or Ay)

Lake Plains & Outwash Plains (cont'd)
- Oakville loamy fine sand (Oa)
- Plumbrook fine sandy loam (Pm)
- Rawson sandy loam (Rc)
- Rimer loamy fine sand (Rg)
- Tuscola fine sandy loam (Tu)

Lake Plains
- Del Ray silt loam (De)
- Milford silty clay loam (Mf)
- Saylesville silt loam (Sb)—side slopes
- Shinrock silt loam (Sh)—knolls
- Shinrock silty clay loam (Sk)—side slopes
- Zurich silt loam (Zu)—side slopes

Lake Plains & Deltas
- Elnora loamy fine sand (En)
- Elnora loamy fine sand (Eo) —on bedrock substratum
- Gilford fine sandy loam (Gd)
- Kibbie fine loamy sand (Kb)
- Oakville loamy fine sand (Oa)

Lake Plains & Beach Ridges
- Bixler loamy fine sand (Bk)
- Oakville loamy fine sand (Oa)
- Rawson sandy loam (Rc)

Beach Ridges
- Conotton loam (Ct) & gravelly loam (Cu)
- Udipsamments-Spinks sand (Uc)—excavations

Alluvial Terraces, Beach Ridges, & Outwash Plains
- Chili loam (Ch)
- Jimtown loam (Jt)

Alluvial Floodplains
- Holly silt loam (Ho)
- Nolin (No)
- Orrville silt loam (Op & Or)
- Tioga loam (Tg)

Organic Material
- Marsh (Mn)

Figure 3.2. Parent materials of the soils mapped in the Old Woman Creek watershed (after Redmond et al. 1971; Ernst and Martin 1994; Martin and Prebonick 1994).

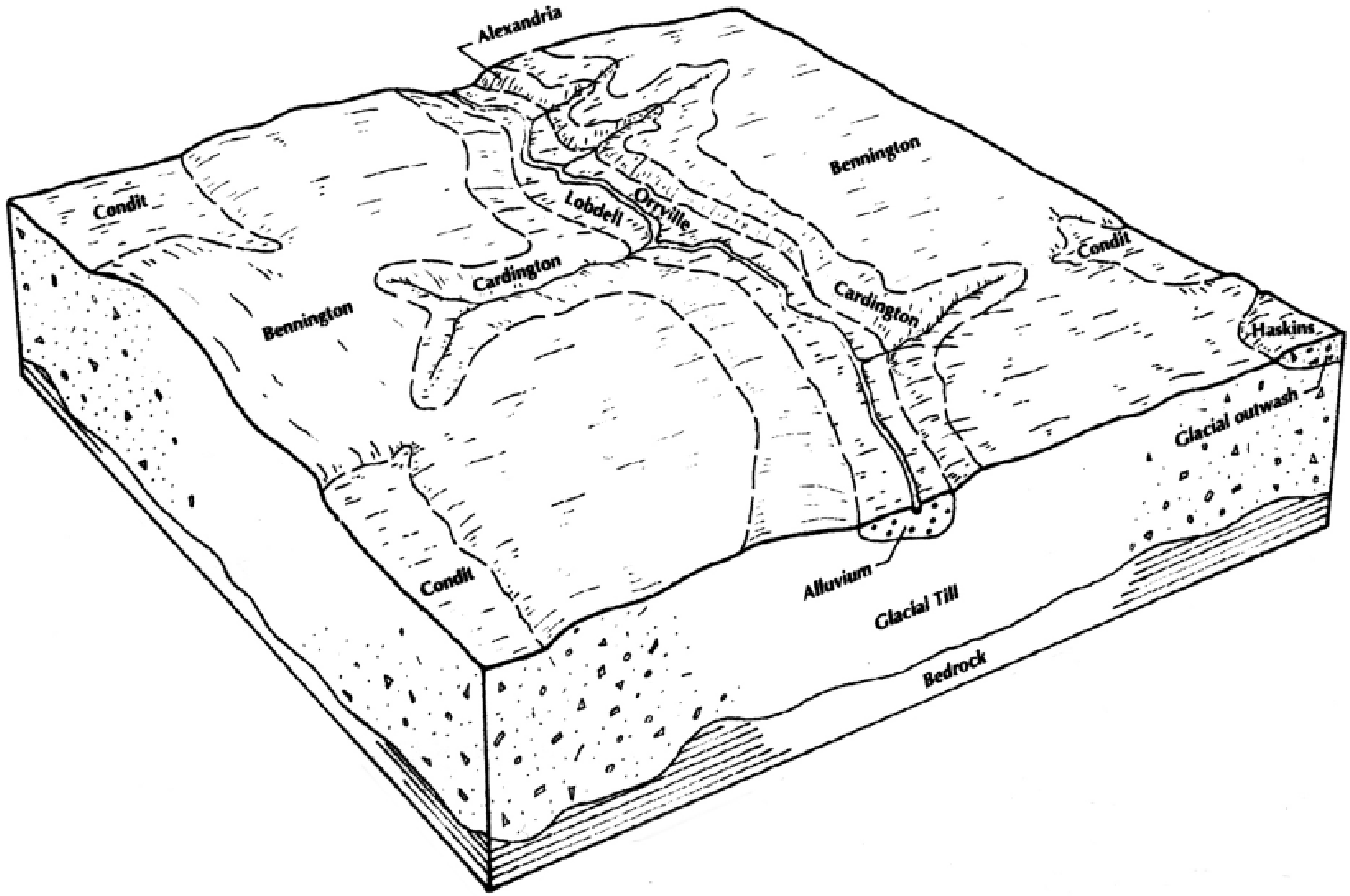


Figure 3.3. Typical soils developed on glacial till parent material in Old Woman Creek watershed (from Ernst and Martin 1994).

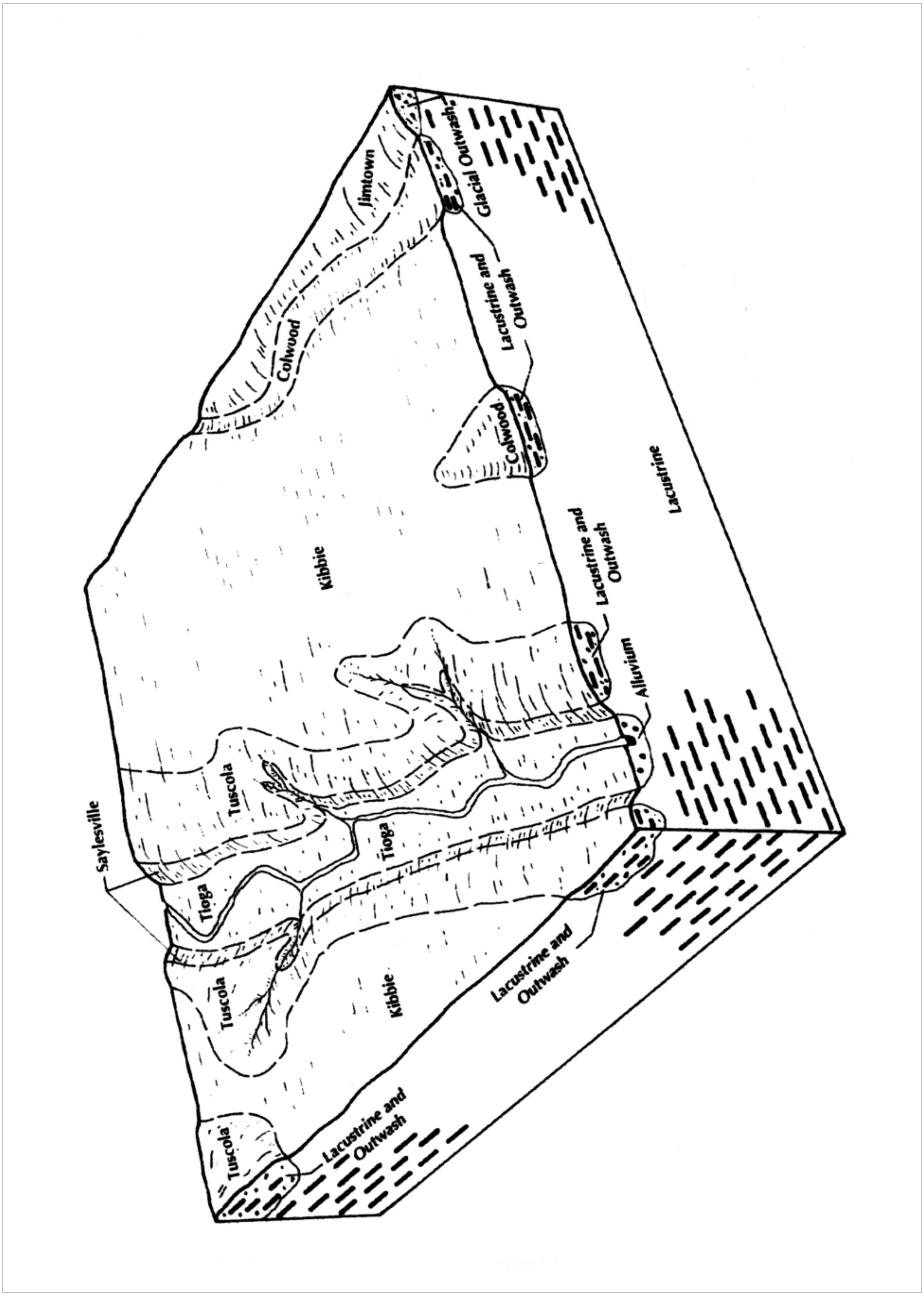


Figure 3.4. Typical soils developed on lacustrine and glacial outwash parent material in Old Woman Creek watershed (from Ernst and Martin 1994).

communities and determine the types of soils that form. Climate regulates the rate of weathering and decomposition of minerals and influences the removal of materials by leaching. The climate is essentially uniform throughout the watershed and does not directly account for differences among the soils.

RELIEF

Soil formation is influenced by relief (variations in height and slope or irregularities of the land surface) which controls the movement of water in the watershed. Runoff, ponding, depth to water table, internal drainage, and accumulation or removal of organic matter are affected by relief. Relief can account for the development of different types of soils from the same kind of parent material. For example, Chili and Millgrove soils both form in porous gravelly outwash deposits. Chili soil is well drained because they are on ridges high above the water table (such as the ancient beaches in the vicinity of Berlin Heights), whereas Millgrove soil is very poorly drained because they are in low areas where the water table is close to the surface (such as the flat land at the base of the Berea Escarpment).

LIVING ORGANISMS

All living organisms are important to soil formation, including plants, animals, fungi, and bacteria. Plants are generally responsible for the amount of organic material, color of the surface layer, and the amount of nutrients in the soil. Animals such as earthworms, cicadas, and other burrowers tend to keep soil open and porous. Fungi and bacteria decompose the vegetation, releasing nutrients for plant assimilation. Most of the soils of the watershed were formed under hardwood forests. For example, Shinrock soil (typical of the side slopes of Old Woman Creek) formed under forests of red oak, white oak, black oak, and other hardwoods. In contrast, Miner soil formed in poorly drained depressions under swamp forests, such as near the headwaters of Old Woman Creek southwest of Berlin Heights. Sisson soil formed on low, dry knolls at the southern end of the estuary, presumably under prairie vegetation. In these sites, the thick, dark-colored surface layer indicates that the native forest was thin enough to permit the growth of a dense stand of prairie grasses.

TIME

For the foregoing soil-forming factors to produce their effects, duration is an important consideration. The length of time that parent material has been exposed to the process of soil formation affects the nature of the soil that forms. Thus, the age of a soil is indicated by the degree of profile development. In general, the longer the time that climate and organisms have acted upon the parent material, the more distinct are the horizons in the profile. The soils in the watershed formed since the last glaciation (about 12,000 years ago). All are approximately the same age, except for the soils formed in recent alluvium. In areas with steep slopes, geological erosion has nearly kept pace with soil formation resulting in a very thin soil layer. Similarly, soils formed in recent alluvium lack well-defined horizons. In flat or gently rolling areas the horizons are much thicker, generally greater than 0.6 m.

SOIL PROFILE

As mentioned above, most soils in the Old Woman Creek watershed have a profile—a series of two or more layers lying one below the other and extending down to unbroken bedrock. These layers, known as horizons, differ from one another in color, texture, structure, and composition (Soil Survey Division Staff 1993). The majority of soil profiles in Old Woman Creek watershed have three principle horizons, identified as A, B, and C (Figure 3.5) and a few have additional layers or horizons, named O, E, and R. The A horizon is a zone of mixed mineral and humified organic material which is undergoing leaching, whereas the B horizon is a zone of mineral and humus accumulation. The A and B horizons together constitute the true soil (solum)—material capable of supporting plants where soil-forming processes occur. In certain soils, above the A horizon is a layer of organic matter, known as the O layer or A_o and A_{oo} horizon, consisting of leaves and decaying plant residue. Much of the watershed has been farmed, thus plowing has tended to mix the O and A horizons into a layer commonly known as topsoil. The B horizon, often called the subsoil, is typically below the plowzone. Between the A and B horizons, a mineral layer (E horizon) can occur in which the main feature is the loss of silicate clay, iron, and/or aluminum, leaving a concentration of sand and silt particles. The C horizon consists of weathered rock material and is

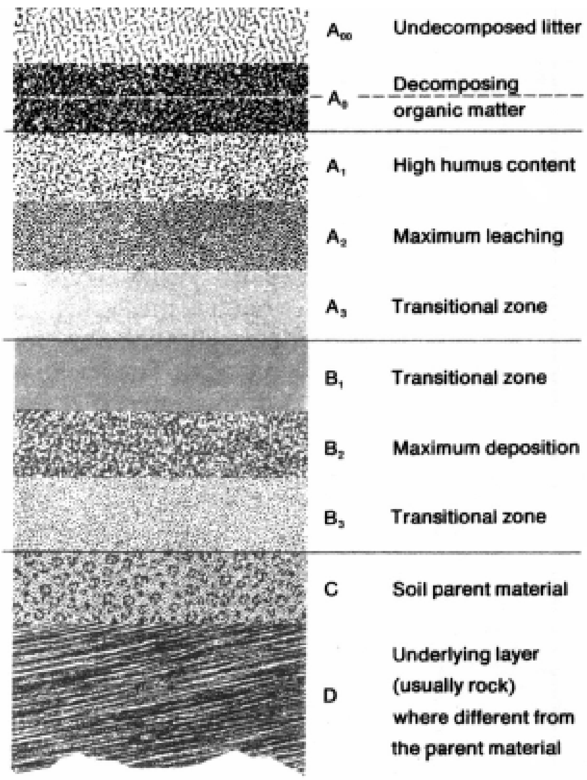


Figure 3.5. Generalized soil profile for Old Woman Creek watershed (from Andrews 1973).

considered to be the parent material for the overlying solum. Because the watershed was glaciated, the last retreating ice sheet left behind massive deposits of till, particularly south of the Berea Escarpment, resulting in a very thick C horizon. The same can be said of the glacial lake deposits in the vicinity of the estuary. Below the C horizon is the R layer or D horizon which is consolidated bedrock.

Each of the principle horizons has subdivisions (layers) designated by numbers and lowercase suffixes (descriptive modifiers) which represent specific features (Figure 3.6). The A horizon is where most living organisms are active. Layer A_1 consists of organic humus and is usually very dark in color, whereas A_2 is lighter in color and is the zone where leaching (eluviation) takes place, continually removing both humus and minerals. A_p is used to indicate a disturbance of the surface layer by pasturing, tillage, or other mechanical means. The transition from horizon A to B is a gradual one, sometimes designated A_3, BE, or B_1. The B_2 layer is usually redder or deeper in color,

DESCRIPTIVE MODIFIERS FOR SOIL HORIZONS

Suffix Modifers
a Highly decomposed organic material
b Buried mineral soil horizon; burial took place after onset of soil formation processes
c Concretions or nodules
d Physical restriction to root penetration
e Organic material of intermediate decomposition
f Frozen soil; permanent ice, not seasonally frozen layer or "dry permafrost"
g Strong gleying; poor drainage resulting in iron reduction (gray soil colors and mottles)
h Illuvial accumulation of organic matter leaching from an upper layer
i Slightly decomposed organic material
k Accumulation of carbonates
m Cementation or induration; cementing agent: carbonate (km), silica (qm), iron (sm); gypsum (ym), lime and silica (kqm), salts more soluble than gypsum (zm)
n Accumulation of sodium
o Residual accumulations of sesquioxides; particularly iron and aluminum clay oxides
p Tillage or other disturbance
q Accumulation of silica
r Weathered or soft bedrock
s Illuvial accumulation of sesquioxides and organic material
ss Presence of slickensides; resulting from swelled clay minerals and shear failure of soil
t Accumulation of silicate clay
v Plinthite; iron-rich, humus-poor, reddish material that is irreversibly hard when dried
w Development of color or structure with no apparent illuvial accumulation of material
x Fragipan character; development of firm, brittle layers between softer, less dense ones
y Accumulation of gypsum
z Accumulation of salts more soluble than gypsum
1,2,3…Vertical subdivisions into layers; higher the number the deeper in the profile; follows letter suffix

Prefix Modifers
2,3… Indicates discontinuities; uppermost material understood to be 1 (number omitted); numbering starts with second layer (generally a contrasting parent material)

Figure 3.6. Symbols and their meanings used to designate subordinate features within soil horizons (after Soil Survey Division Staff 1993).

the result of iron and manganese oxides deposition (illuvation) that have been leached from the A horizon by groundwater. In certain soils, humus, clay, and calcium also accumulate in the B_2 layer. The B_3 or BC layer is a transition zone to the parent material, C horizon, which contains no humus and is lighter in color than the B horizon.

SOIL CHARACTERISTICS AND LIMITATIONS

The varying properties and limitations of the soils in Old Woman Creek watershed influence the types of land use activity found in the watershed (see Land Use chapter of this profile). Table 3.2 provides a summary of texture, hydrology, slope, land capability, and crop productivity for each of the 67 soil types in the watershed. A total of 38 of the soil types are considered prime farmland, accounting for 82% of the land surface. Table 3.3 lists the properties and limitations of the various soils in the watershed, including parent material, slope, drainage, water capacity, water table, depth to bedrock, and hazards. Flooding is the most common soil hazard, but only four soils (Holly, Nolin, Orrville, and Tioga) are susceptible to serious problems. These soils occupy about 4% of the watershed's area. Table 3.4 gives rainfall and wind erosion factors for each of the soils in the watershed. Most soils have low- to moderate-erosion factors.

SOIL EROSION AND SEDIMENT YIELD

Soil erosion and resultant sediment yields in the watershed have a potential impact on the water quality and infilling of Old Woman Creek estuary (Figure 3.7). Soil erosion is the rate of removal of soil particles from a specified area per unit time, either measured in soil mass or soil thickness, whereas, sediment yield refers to the rate at which sediment passes a particular point in a drainage basin per unit time. While soil erosion values can be used to document the annual soil loss at a specific location, sediment yield values provide a measure of the flow of sediment through a drainage basin. Sediment yield depends on: (1) input functions including soil erosion, mass wasting, and, atmospheric fallout, (2) interbasinal storage such as deposition in stream valleys and upland gullies or rills, and (3) output function comprised of stream sediment load and wind erosion. Stream sediment loads are typically divided into three components: (1) bedload (particles that slide, roll, or saltate along the steam bed), (2) suspended load (particles that are carried in the water column, generally by turbulence), and (3) dissolved load (chemicals in solution or adsorbed to colloids).

Using a Geographical Information System (GIS) based model, Evans and Seamon (1997) found that soil erosion within the Old Woman Creek watershed varied from 1.6 to 97.3 metric tons/ha/yr depending on soil type, topography, rainfall, and land use practices. Using a basin-wide average of 7.3 metric tons/ha/yr, this equates to a total soil loss of 50,484 metric tons/yr for the entire Old Woman Creek watershed. These values compare reasonably well with corrected calculations made by Buchanan (1982) using the Universal Soil Loss Equation (USLE) – average soil loss of 5.8 metric tons/ha/yr. The higher values obtained by Evans and Seamon (1997) are most likely a consequence of their greater sampling density and the use of the Revised Universal Soil Loss Equation (RUSLE).

The Universal Soil Loss Equation (Wischmeier and Smith 1965) determines soil erosion loss (A) as a function of rainfall energy and intensity (R), soil erodibility (K), slope length (L), slope gradient (S) soil cover (C), and conservation practices (P). The Revised Universal Soil Loss Equation (Renard et al. 1993) has the same form, but includes revisions for: (1) slope length and slope gradient calculations, (2) more elaborate calculations for soil cover and conservation practices, and (3) and new terms to account for freeze-thaw effects and rill formation on erosion. Thus, the RUSLE/USLE values for soil erosion (loss in mass/area/unit time) are the product of these factors which can be expressed as: $A=RKLSCP$. Determining the total soil loss for a heterogeneous drainage basin, such as Old Woman Creek, required summation of losses for nearly 5,000 polygons (120-m grid spacing).

The southeastern portion of Old Woman Creek watershed appears to be the most significant in terms of soil erosion, sediment yield, and resultant loadings. This region is characterized by Bennington-Cardington-Condit association soils (Ernst and Martin 1994, Martin and Prebonick 1994) which have the highest erodibility in the watershed (K=0.37–0.43). This region also lies at the transition from till plain to escarpment where slopes are greatest.

Extrapolation of soil loss data to sediment yields requires the calculation of delivery ratios, or inversely, interbasin storage ratios, for the watershed. Delivery ratios refer to the percentage of eroded sediment that is transported to a specified point in the watershed, essentially the amount of soil erosion less redeposited sediment in the form of storage. Evans and Seamon (1997) calculated sediment delivery ratios for the watershed above the estuary (84% of basin) using three hydrological data sets from earlier studies (Buchanan 1982, Woods 1987, Krieger 1993). These studies indicated that the annual suspended sediment load (approximately 3,400 metric tons/yr) is 30-35% of the total average annual stream sediment load (approximately 10,500 metric tons/yr). The calculated delivery ratios ranged from 21–25%, indicating interbasin storage between 75-79% of the soil eroded within the drainage basin. Figure 3.8 illustrates the annual rate of soil loss (tons/hectares) for 4,834 polygons created by a 120-meter grid spacing over the entire Old Woman Creek drainage basin using the RUSLE method.

Thus, on the average it takes four to five years for soil eroded in the watershed to make its way to the estuary. Considering that at Ordinary High Water level (174.77 m, IGLD 1985 or 1.28 m above Low Water Datum) the estuary has a volume of approximately 342,000 m^3 (Herdendorf and Hume 1991) and using a specific gravity of about 2.0 for compacted sediment (Lyon and Buckman 1943), the annual sediment load to the estuary of 10,500 metric tons (equivalent to 5,250 m^3) would completely fill the estuary in some 65 years if sediment was not passed through to Lake Erie. Fortunately for the estuary, a good deal of the annual sediment load is eventually resuspended and carried to the lake. The sediment balance in the estuary appears to be at a near steady-state condition. Bathymetric surveys of Old Woman Creek estuary were made in 1977 (Buchanan 1982) and 1990 (Herdendorf and Hume 1991). During the 1977 survey the mean water level in the estuary was 0.9 m above LWD and the mean water depth was 0.3 m; whereas in 1990 the mean estuary level was 1.0 m above LWD and the mean depth was 0.37 m. Given the differences in survey methods, these findings are extremely close, indicating that the estimated 68,000 m^3 of sediment delivered to the estuary in the 13-year period (1977–1990) could not be accounted for by shoaling of the bottom. Evenly distributing 68,000 m^3 of sediment on the bottom of the estuary would have resulted in a shallowing of approximately 0.3 m, a situation that did not occur.

Figure 3.7. Aerial view of lake plain soils in Old Woman Creek valley immediately upstream of the estuary (Linda Feix).

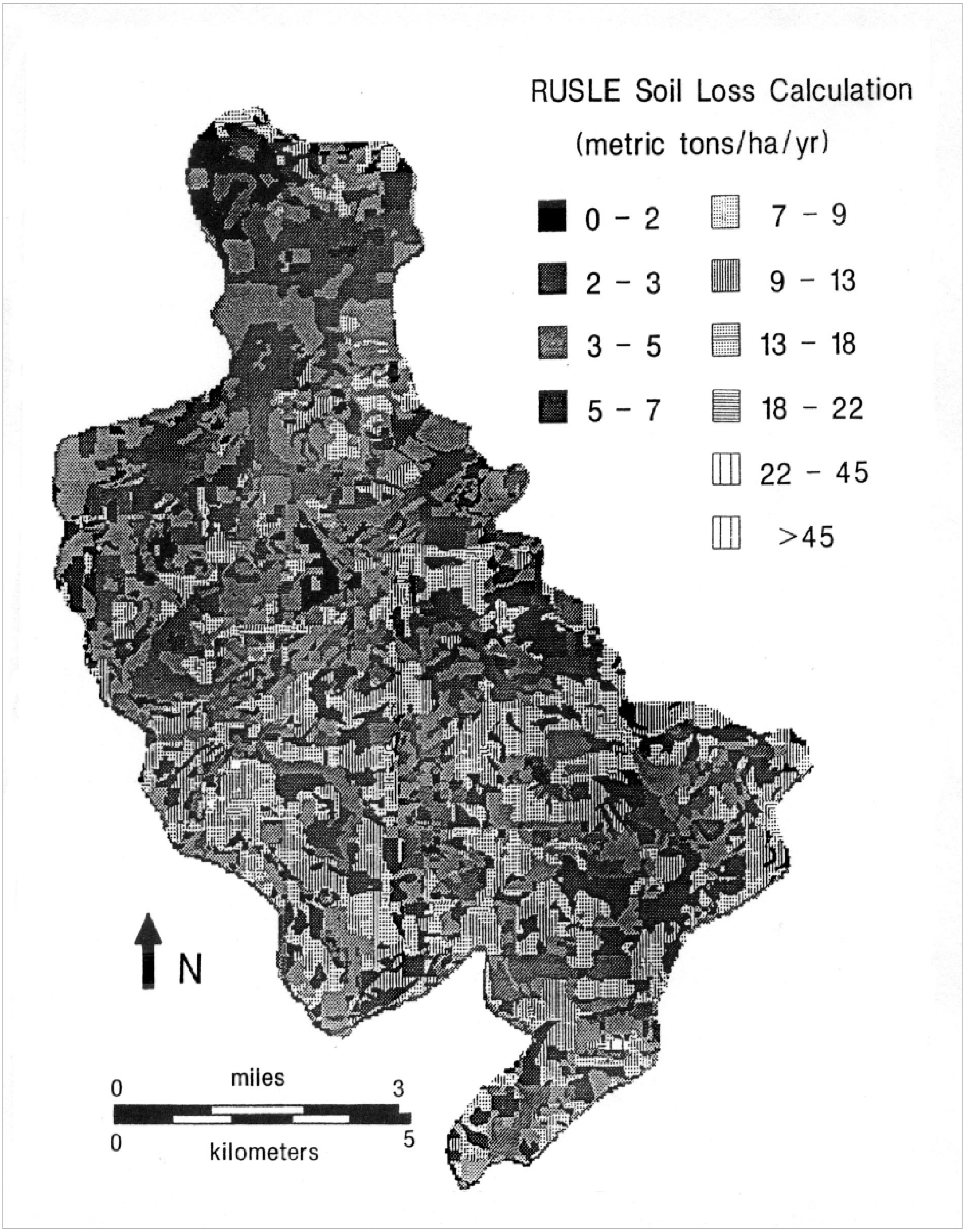


Figure 3.8. Calculation of soil loss for Old Woman Creek watershed expressed in tons per hectare for polygons created by a 120-meter grid spacing (1.44 ha/grid cell) using the RUSLE method (from Evans and Seamon 1997).

TABLE 3.1. OLD WOMAN CREEK WATERSHED SOILS: SUMMARY OF AREAS IN HECTARES BY TOWNSHIP

Map Symbol	Soil Series	Berlin Twp	Florence Twp	Huron Twp	Milan Twp	Erie Co.	Townsend Twp	Wakeman Twp	Huron Co.	TOTAL
Aa	Adrian	4.2				4.2				4.2
AkA	Allis	73.5				73.5				73.5
AmD2	Amanda	8.6				8.6				8.6
AnG	Amanda-Dekalb	41.7				41.7				41.7
AvA (OgA)	Avery (Ogontz)	51.1		16.9	2.0	70.0				70.0
AyB (OhB)	Avery (Ogontz)	53.6		4.6	10.5	68.7				68.7
Bc	Beaches	1.0				1.0				1.0
BeA	Bennington	218.0	2.4			220.4				220.4
BgA	Bennington	301.1	55.7			356.8	940.7	8.3	949.0	1,305.8
BgB	Bennington	156.8	21.2			178.0	147.8		147.8	325.8
BkA	Bixler	249.7	3.8	28.5	12.7	294.7	0.1		0.1	294.8
BkB	Bixler	24.8	2.0	2.6	1.4	30.8				30.8
BvG	Brecksville	10.9				10.9				10.9
CaB (CdB)	Cardington	51.7	25.6			77.3	336.0		336.0	413.3
CbC2	Cardington	32.2				32.2				32.2
ChB	Chili	22.9	0.2			23.1				23.1
Cm	Colwood	33.3		26.8	24.9	85.0	0.5		0.5	85.5
Co	Condit	218.9	36.5			255.4	69.2	3.3	72.5	327.9
CtB	Conotton	16.3				16.3				16.3
CuC	Conotton	16.5				16.5				16.5
DbB	Dekalb	42.7				42.7				42.7
DbD	Dekalb	10.1				10.1				10.1
DeA	Del Rey	184.7		0.3	2.1	187.1				187.1
EnA	Elnora	226.4		33.3	36.8	296.5	15.0		15.0	311.5
EoA	Elnora	1.9				1.9				1.9
Fn	Fluvaquents	63.7		0.1		63.8				63.8
Fr	Fries	14.5				14.5				14.5
Gd	Gilford	60.9		2.8	17.7	81.4				81.4
HkA	Haskins	327.6	10.1			337.7	11.6		11.6	349.3
Ho	Holly	243.7	17.6			261.3	1.2		1.2	262.5
JtA	Jimtown	196.4	1.6			198.0	3.2		3.2	201.2
KbA	Kibbie	240.4		3.8	20.7	264.9				264.9
Me	Mermill	314.7				314.7				314.7
Mf	Milford	65.3		1.7	0.2	67.2				67.2

(CdB, MwB, OgA, OhB, Ps)—designates corresponding soil names in Huron County

TABLE 3.1. OLD WOMAN CREEK WATERSHED SOILS: SUMMARY OF AREAS IN HECTARES BY TOWNSHIP (cont'd)

Map Symbol	Soil Series	Berlin Twp	Florence Twp	Huron Twp	Milan Twp	Erie Co.	Townsend Twp	Wakeman Twp	Huron Co.	TOTAL
Mg	Millgrove	121.5				121.5				121.5
Mr	Miner	1.3				1.3				1.3
MxA	Mitiwanga	78.3	0.6			78.9				78.9
MxB (MwB)	Mitiwanga	23.8				23.8	15.1		15.1	38.9
No	Nolin	1.2				1.2				1.2
OaB	Oakville	49.3	2.9	1.0		53.2				53.2
Op	Orrville	34.3				34.3				34.3
Or	Orrville	28.7				28.7	5.3		5.3	34.0
OsB	Oshtemo	253.0			1.1	254.1	0.4		0.4	254.5
Pc	Pewamo	11.8				11.8				11.8
Pg (Ps)	Pits	3.6				3.6				3.6
Pk	Pits (quarry)	0.1				0.1	8.4		8.4	8.5
PmA	Plumbrook	21.9			3.3	25.2				25.2
RcA	Rawson	15.6	1.7			17.3				17.3
RcB	Rawson	108.4	9.8			118.2				118.2
RgA	Rimer	64.5				64.5				64.5
SbF	Saylesville	7.6				7.6				7.6
ShB	Shinrock	9.5				9.5				9.5
SkC2	Shinrock	4.3				4.3				4.3
SpB	Spinks	38.4		0.2	0.1	38.7	0.7		0.7	39.4
SpD	Spinks	26.7				26.7				26.7
Tg	Tioga	5.9				5.9				5.9
TuA	Tuscola	22.6				22.6				22.6
TuB	Tuscola	32.4			3.1	35.5				35.5
Uc	Udipsamments-Spinks	40.5				40.5				40.5
Ud	Udorthents	34.6		10.8	2.1	47.5				47.5
W	Water body	27.0				27.0	1.2		1.2	28.2
WaB	Wakeman	72.3				72.3	6.9		6.9	79.2
WaC	Wakeman	14.4				14.4				14.4
ZuC2	Zurich	38.4		4.6	3.3	46.3				46.3
ZuD2	Zurich	32.6		1.4		34.0				34.0
ZuE2	Zurich	29.1				29.1				29.1
ZuF	Zurich	150.4				150.4				150.4
TOTAL		4,983.8	191.7	139.4	142.0	5,456.9	1,563.3	11.6	1,574.9	7,031.8

TABLE 3.2. CHARACTERISTICS OF OLD WOMAN CREEK WATERSHED SOILS

Soil Series	Map Symbol	Texture	Hydric	Slope	Land Capability	Prime Farmland	Relative Productivity	Hazard/ Limitation	Area within Watershed (ha)
Adrian	Aa	muck	yes	0-2%	Vw	no	—	subsidence	4.2
Allis	AkA	silty clay loam	yes	0-2%	IVw	no	48	poor drainage	73.5
Amanda	AmD2	loam	no	12-18%	IVe	no	52	eroded	8.6
Amanda-Dekalb	AnG	rocky	no	40-70%	VIIe	no	—	bedrock outcrop	41.7
Avery (Ogontz)	AvA (OgA)	fine sandy loam	no	0-2%	I	yes	79	slight	70.0
Avery (Ogontz)	AyB (OhB)	silt loam	no	2-6%	IIe	yes	76	seasonal HWT	68.7
Beaches	Bc	sand & fine gravel	no	0-12%	—	no	—	wave action	1.0
Bennington	BeA	loam	no	0-2%	IIw	yes*	73	poor drainage	220.4
Bennington	BgA	silt loan	no	0-2%	IIw	yes*	73	poor drainage	1,305.8
Bennington	BgB	silt loam	no	2-6%	IIe	yes*	70	poor drainage	325.8
Bixler	BkA	loamy fine sand	no	0-2%	IIw	yes*	67	poor drainage	294.8
Bixler	BkB	loamy fine sand	no	2-6%	IIe	yes*	67	poor drainage	30.8
Brecksville	BvG	silt loam	no	40-70%	VIIe	no	—	slippage	10.9
Cardington	CaB	silt loam	no	2-6%	IIe	yes	70	seasonal HWT	413.3
Cardington	CbC2	silty clay loam	no	6-12%	IIIe	no	64	eroded	32.2
Chili	ChB	loam	no	2-6%	IIe	yes	67	slight	23.1
Colwood	Cm	loam	yes	0-2%	IIw	yes*	100	poor drainage	85.5
Condit	Co	silt loam	yes	0-2%	IIIw	yes*	61	poor drainage	327.9
Conotton	CtB	loan	no	2-6%	IIIs	yes	52	droughty	16.3
Conotton	CuC	gravelly loam	no	6-12%	IVe	no	48	erosion risk	16.5
Dekalb	DbB	channery loam	no	2-6%	IIe	no	52	sandstone slabs	42.7
Dekalb	DbD	channery loam	no	12-18%	IVe	no	45	sandstone slabs	10.1
Del Rey	DeA	silt loam	no	0-2%	IIw	yes*	73	poor drainage	187.1
Elnora	EnA	loamy fine sand	no	0-4%	IIw	no	55	rapid permeability	311.5
Elnora	EoA	loamy fine sand/rock	no	0-4%	IIw	no	55	rapid permeability	1.9
Fluvaquents	Fn	silty	yes	0-2%	—	no	—	frequent floods	63.8
Fries	Fr	silty clay loam	yes	0-2%	IIIw	yes*	48	poor drainage	14.5
Gilford	Gd	fine sandy loam	yes	0-2%	IIw	yes*	91	poor drainage	81.4
Haskin	HkA	loam	no	0-2%	IIw	yes*	76	poor drainage	349.3
Holly	Ho	silt loam	yes	0-2%	IIIw	yes*	36	occasional floods	262.5
Jimtown	JtA	loam	no	0-2%	IIw	yes*	76	poor drainage	201.2
Kibbie	KbA	fine sandy loam	no	0-2%	IIw	yes*	85	poor drainage	264.9
Mermill	Me	silty clay loam	yes	0-2%	IIw	yes*	97	poor drainage	314.7
Milford	Mf	silty clay loam	yes	0-2%	IIw	yes*	91	poor drainage	67.2
Millgrove	Mg	loam	yes	0-2%	IIw	yes*	100	poor drainage	121.5
Miner	Mr	silty clay loam	yes	0-2%	IIIw	yes*	79	poor drainage	1.3

TABLE 3.2. CHARACTERISTICS OF OLD WOMAN CREEK WATERSHED SOILS (cont'd)

Soil Series	Map Symbol	Texture	Hydric	Slope	Land Capability	Prime Farmland	Relative Productivity	Hazard/ Limitation	Area within Watershed (ha)
Mitiwanga	MxA	silt loam	no	0-2%	IIw	yes*	67	poor drainage	78.9
Mitiwanga	MxB	silt loam	no	2-6%	IIe	yes*	64	shallow bedrock	38.9
Nolin	No	silt loam	no	0-2%	IIw	yes	85	occasional floods	1.2
Oakville	OaB	loamy fine sand	no	0-6%	IVs	no	45	droughty	53.2
Orrville	Op	silt loam/bedrock	no	0-2%	IIw	yes*	73	occasional floods	34.3
Orrville	Or	silt loam/bedrock	no	0-2%	IIw	yes**	67	frequent floods	34.0
Oshtemo	OsB	loamy sand	no	0-6%	IIIs	yes	55	droughty	254.5
Pewamo	Pc	silty clay loam	yes	0-2%	IIw	yes*	91	poor drainage	11.8
Pits	Pg	sand & gravel	no	—	—	no	—	excavation	3.6
Pits (quarry)	Pk	sandstone bedrock	no	—	—	no	—	exposed bedrock	8.5
Plumbrook	PmA	fine sandy loam	no	0-2%	IIw	yes*	97	seasonal HWT	25.2
Rawson	RcA	sandy loam	no	0-2%	I	yes	76	slight	17.3
Rawson	RcB	sandy loam	no	2-6%	IIe	yes	73	seasonal HWT	118.2
Rimer	RgA	loamy fine sand	no	0-2%	IIw	no	73	poor drainage	64.5
Saylesville	SbF	silt loam	no	25-40%	VIIe	no	—	erosion risk	7.6
Shinrock	ShB	silt loam	no	2-6%	IIe	yes	70	seasonal HWT	9.5
Shinrock	SkC2	silty clay loam	no	6-12%	IIIe	no	64	eroded	4.3
Spinks	SpB	loamy fine sand	no	0-6%	IIIs	no	48	droughty	39.4
Spinks	SpD	loamy fine sand	no	12-18%	IVe	no	42	erosion risk	26.7
Tioga	Tg	loam	no	0-2%	IIw	yes	79	occasional floods	5.9
Tuscola	TuA	fine sandy loam	no	0-2%	I	yes	79	slight	22.6
Tuscola	TuB	fine sandy loam	no	2-6%	IIe	yes	76	seasonal HWT	35.5
Udipsam.-Spinks	Uc	sandy	no	0-6%	—	no	36	excavation	40.5
Udorthents	Ud	loamy; mixed fill	no	—	—	no	—	fill material	47.5
Wakeman	WaB	sandy loam	no	2-6%	IIe	yes	67	shallow bedrock	28.2
Wakeman	WaC	sandy loam	no	6-12%	IIIe	no	61	shallow bedrock	79.2
Water	W	sediment	yes	—	—	no	—	water saturated	14.4
Zurich	ZuC2	silt loam	no	6-12%	IIIe	no	70	eroded	46.3
Zurich	ZuD2	silt loam	no	12-18%	IVe	no	64	eroded	34.0
Zurich	ZuE2	silt loam	no	18-25%	VIIe	no	52	erosion risk	29.1
Zurich	ZuF	silt loam	no	25-40%	VIIe	no	—	erosion risk	150.4
									7,031.8

TABLE 3.2. CHARACTERISTICS OF OLD WOMAN CREEK WATERSHED SOILS (cont'd)

LEGEND:

Soil Series – group of soils with similar subsurface profiles; series have horizons that are nearly consistant in composition, thickness, and arrangement.

Special Soils:

- Beaches – material, mainly sand and gravel, heaped up the action of waves, currents, and wind on the shore of a glacial or modern large lake; beach ridges are low, somewhat continuous mounds of beach and dune material.
- Fluvaquents – taxonomic group of soils with a seasonal high water table that formed in recent alluvium; found near the mouth of Old Woman Creek where flooding is controlled by the level of Lake Erie .
- Pits – areas excavated for gravel or sand (Pg) and bedrock quarries in Berea Sandstone (Pk).
- Udipsamments – taxonomic group of soils with relatively little evidence of soil formation; found in areas where sand has been excavated for construction material.
- Udorthents – soils in areas that have been excavated or where fill material has been deposited.
- Water – lakes, ponds, and reservoirs sediments.

Map Symbol – consists of a 2-letter code (first letter capital and second letter lower case) designating the soil series to which the map unit belongs; can be followed by a single capital letter (A-G) indicating the amount of <u>slope</u>; can be followed by a single number (1-4) indicting the <u>erosion class</u> (see below):

Slope – inclination of and surface from horizontal; percentage of slope is the vertical distance divided by the horizontal distance times 100.

- No letter – flat (0-1% slope)
- A – nearly level (0-2% slope)
- B – gently sloping (2-6% slope)
- C – sloping (6-12% slope)
- D – moderately steep (12-18% slope)
- E – steep (18-25% slope)
- F – very steep (25-40% slope)
- G – very steep (40-70% slope)

Erosion Class – pertains to proportion of upper horizons that have been removed by accelerated water and wind erosion.

- Class 1 – <25% loss of A and/or E horizons
- Class 2 – 25-75% loss of A and/or E horizons
- Class 3 – >75% loss of A and/or E horizons
- Class 4 – 100% loss of A and/or E horizons

Texture – relative proportions of sand, silt, and clay particles in a soil; basic textural classes, in order of increasing proportion of fine particles progress from sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, to clay.

Hydric – soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part.

TABLE 3.2. CHARACTERISTICS OF OLD WOMAN CREEK WATERSHED SOILS (cont'd)

LEGEND: (cont'd)

Land Capability – degree of limitations on soil use

Class I – soils with slight limitations restricting their use

Class II – soils with severe limitations which reduce the choice of plants (require moderate conservation practices)

Class III – soils with severe limitations which reduce the choice of plants (require special conservation practices)

Class IV – soils with very severe limitations which reduce the choice of plants (require very special conservation practices)

Class V – soils which are not likely to erode but have other limitations (impractical to overcome) that limit their use

Class VI – soils with severe limitations that make them generally unsuitable for cultivation

Class VII – soils with very severe limitations that make them unsuitable for cultivation

Class VIII – soils with very severe limitations that nearly preclude their use for crop production

Modifiers – lower case letters indicate special limitations:

e – risk of erosion unless close growing plant cover is maintained

w – water on or in the soil interferes with plant growth or cultivation (artificial drainage may be required for cultivation)

s – shallow, droughty, or stony conditions

Prime Farmland – land that is best suited to food, feed, forage, fiber, and oilseed crops; produces the highest yields with minimal imputs of energy and economic resources; farming it results in the least damage to the environment; not urban and built-up land or water areas.

* – prime farmland where drained

** – prime farmland where drained and either protected from flooding or not frequently flooded during growing season

Relative Productivity – index number based on the most productive soils in the watershed (Cm and Mg) which have been assigned an index number of 100; index numbers for the other map units indicate the percentage of their corn yield compared to a yield of 15 cubic meters per hectare (165 bushels per acre) for Cm and Mg soil map units.

Hazard/Limitation – features of the soil or site that makes it hazardous or limits its use.

HWT – high water table

Data Source:

U.S. Dept. Agriculture, Soil Conservation Service and Ohio Dept. Natural Resources, Div. Soil & Water Conservation (Redmond et al. 1971, Ernst and Martin 1994, Martin and Prebonick 1994)

TABLE 3.3. PROPERTIES AND LIMITATIONS OF OLD WOMAN CREEK WATERSHED SOILS ERIE AND HURON COUNTIES, OHIO

Soil Series (Map Symbol)	Location/ Parent Material	Slope	Drain	Permeability	Water Capacity	Water Table High	Bedrock	Shrink/Swell	Homesite Limitation	Hazard
Adrian (Aa)	former bogs	0-2%	v poor	moderate	very high	surface (H)	>1,5 m	low	severe (B,St)	subsidence
Allis (Ak)	till or lake plains	0-2%	poor	very slow	low	surface (H)	0.5-1.0 m (C)	moderate	severe (St)	none
Amanda (Am)	till plain slopes	12-18%	well (E)	moderate slow	high	>1.2 m	>1.5 m	moderate	severe (St)	none
Amanda-Dekalb (An)	bedrock outcrops	40-70%	well	rapid	very low	>1.8 m	0.5-1.0 m	low	severe (B,St)	large stones
Bennington (Be,Bg)	till or lake plains	0-6%	s poor	slow	moderate	0.3-0.8 m	>1.5 m	moderate	severe (St)	none
Bixler (Bk)	lake plain/beach ridges	0-6%	s poor	rapid/moderate	moderate	0.5-1.0 m	>1.5 m	moderate	severe (B,St)	none
Brecksville (Bv)	bedrock slopes	40-70%	well	slow	low	>1.8 m	0.5-1.0 m (C)	moderate	severe (Sl,St)	slippage
Cardington (Ca,)	till plain	0-6%	moderate	slow	moderate	0.5-1.0 m	>1.5 m	moderate	severe (B,St)	none
Cardington (Cb)	till plain	6-12%	well (E)	moderate slow	moderate	0.5-1.0 m	>1.5 m	moderate	severe (B,St)	none
Chili (Ch)	beach ridges/outwash	2-6%	well	moderate rapid	moderate	>1.8 M	>1.5 m	low	slight	none
Colwood (Cm)	lake/outwash plains	0-2%	v poor	moderate slow	high	surface (H)	>1.0 m	moderate	severe (St)	none
Condit (Co)	till plain	0-2%	poor	slow	moderate	surface (H)	>1.5 m	moderate	severe (St)	none
Conotton (Ct,Cu)	beach ridges	2-12%	well	rapid	low	>1.8 m	>1.5 m	low	severe (St)	none
Dekalb (Db)	bedrock knolls	2-18%	well	rapid	very low	>1.8 m	0.5-1.0 m (C)	low	severe (St)	large stones
Del Rey (De)	lake plain	0-2%	s poor	slow	moderate	0.3-0.9 m	>1.5 m	moderate	severe (St)	none
Elnora (En,Eo)	lake plain or deltas	0-4%	moderate	rapid	low	0.4-0.6 m	>1.5; 1-1.5 m	low	severe (B,St)	none
Fries(Fr)	till or lake plains	0-2%	v poor	slow	low	surface (H)	0.5-1.0 m (C)	high	severe (St)	none
Gilford (Gd)	lake plain or deltas	0-2%	v poor	moderate rapid	low	surface (H)	>1.5 m	low	severe (St)	none
Haskins (Hk)	till plain/outwash	0-2%	s poor	moderate/slow	moderate	0.3-0.8 m	>1.5 m	moderate	severe (St)	none
Holly (Ho)	flood plains	0-2%	poor	moderate	very high	surface (H)	>1.5 m	low	severe (St)	flooding
Jimtown (Jt)	outwash/beach ridges	0-2%	s poor	moderate	moderate	0.3-0.8 m	>1.5 m	low	severe (St)	nonw
Kibbie (Kb)	lake plain or delta	0-2%	s poor	moderate	high	0.3-0.6 m	>1.5 m	low	severe (St)	none
Mermill (Me)	lake or till plains	0-2%	v poor	moderate/slow	moderate	surface (H)	>1.5 m	moderate	severe (St)	none
Milford (Mf)	lake plain	0-2%	v poor	moderate slow	high	surface (H)	>1.5 m	moderate	severe (St)	none
Millgrove (Mg)	outwash plains	0-2%	v poor	moderate	moderate	surface (H)	>1.5 m	moderate	severe (St)	none
Miner (Mr)	till or lake plains	0-2%	v poor	slow	moderate	surface (H)	>1.0 m	moderate	severe (St)	none
Mitiwanga (Mx)	till or lake plains	0-6%	s poor	moderate	low	0.3-0.8 m	0.5-1.0 m (C)	moderate	severe (St)	none
Nolin (No)	floor plains	0-2%	well	moderate	high	1.0-1.8 m	>1.5 m	low	severe (St)	flooding
Oakville (Oa)	lake plain/beach ridges	0-6%	well	rapid	low	>1.8 m	>1.5 m	low	severe (St)	none
Ogontz (Og,Oh)*	lake/outwash plains	0-6%	moderate	moderate	high	0.5-1.0 m	>1.5 m	moderate	severe (B,St)	none
Orrville (Op,Or)	flood plains	0-2%	s poor	moderate	high	0.3-0.8 m	>1.5 m	low	severe (St)	flooding
Oshtemo (Os)	outwash/beach ridges	0-6%	well	moderate rapid	low	>1.8 m	>1.5 m	low	slight	none
Pewamo (Pe)	till or lake plains	0-2%	v poor	moderate slow	high	surface (H)	>1.5 m	moderate	severe (St)	none
Plumbrook (Pm)	lake plain/outwash	0-2%	s poor	moderate rapid	moderate	0.3-0.8 m	>1.5 m	low	severe (St)	none

TABLE 3.3. PROPERTIES AND LIMITATIONS OF OLD WOMAN CREEK WATERSHED SOILS ERIE AND HURON COUNTIES, OHIO (cont'd)

Soil Series (Map Symbol)	Location/ Parent Material	Slope	Drain	Permeability	Water Capacity	Water Table High	Bedrock	Shrink/Swell	Homesite Limitation	Hazard
Rawson (Rc)	till or lake plains	0-6%	moderate	moderate/slow	moderate	0.6-1.0 m	>1.5 m	moderate	severe (B,St)	none
Rimer (Rg)	outwash/till plain	0-2%	s poor	moderate rapid	low	0.3-0.8 m	>1.5 m	high	severe (B,St)	none
Saylesville (Sb)	lake plain slopes	25-40%	well	moderate slow	high	>1.8 m	>1.5 m	moderate	severe (St)	none
Shinrock (Sh)	lake plain knolls	2-6%	moderate	moderate slow	moderate	0.6-1.0 m	>1.5 m	low	severe (B.St)	none
Shinrock (Sk)	lake plain slopes	6-12%	well (E)	moderate slow	moderate	0.6-1.0 m	>1.5 m	low	severe (B.St)	none
Spinks (Sp)	beach ridges/outwash	0-18%	well	moderate rapid	low	>1.8 m	>1.5 m	low	severe (St)	none
Tioga (Tg)	flood plains	0-2%	well	moderate/rapid	moderate	1.0-1.8 m	>1.5 m	low	severe (St)	flooding
Tuscola (Tu)	lake plain/outwash	0-6%	moderate	moderate	high	0.6-1.0 m	>1.5 m	moderate	severe (B,St)	none
Wakeman (Wa)	beach ridges/outwash	2-12%	well	moderate rapid	moderate	>1.8 m	0.5-1.0 m (C)	low	severe (B,St)	none
Zurich (Zu)	lake plain slopes	6-40%	well (E)	moderate	high	>1.8 m	>1.5 m	moderate	severe (St)	none

* former name Avery (Av,Ay)

LEGEND:

Soil Series – group of soils with similar subsurface profiles; soils of a particular series have horizons that are nearly consistant in composition, thickness, and arrangement.

Location/Parent Material – physiographic or geologic terrain; bedrock or unconsolidated mineral or organic material from which a soil formed.

Slope – inclination of the land surface from horizontal; percentage of slope is the vertical distance divided by the horizontal distance times 100.

Drain – drainage class; frequency and duration of periods of saturation during formation of soil (not saturation as a result of artifically altered drainage or irrigation):

- **well** – water is drained from soil readily, but not rapidly, and is available to plants throughout most of the growing season; wetness does not inhibit growth of roots
- **moderate** – water is drained from soil somewhat slowly and soils are wet for a short time during the growing season, but long enough that most crops are affected
- **s poor** – somewhat poorly drained soil that is wet for significant periods during the growing season; wetness restricts growth of crops unless artificially drained
- **poor** – water is drained so slowly that soil is saturated periodically during the growing season; free water is commonly at or near the surface so that most crops fail
- **v poor** – very poorly drained soil so that free water remains at or on the surface during most of the growing season; depressions are frequently ponded
- **(E)** – eroded; erosion has changed the soil to such an extent that different management practices are required for uses other than agriculture; 25-75% original topsoil lost

Permeability – quality of the soil that enables water to move downward through the profile; measured in centimeters per hour (cm/hr):

- **very slow** – <0.15 cm/hr
- **slow** – 0.15-0.5 cm/hr
- **moderate slow** – 0.5-1.5 cm/hr
- **moderate** – 1.5-5.0 cm/hr
- **moderate rapid** – 5.0-15 cm/hr
- **rapid** – 15-50 cm/hr
- **very rapid** – >50 cm/hr

TABLE 3.3. PROPERTIES AND LIMITATIONS OF OLD WOMAN CREEK WATERSHED SOILS ERIE AND HURON COUNTIES, OHIO (cont'd)

LEGEND: (cont'd)

Water Capacity – available capacty of the soil to hold water for use by most plants; commonly defined as the difference between the amount of soil water at field capacity and the amount of moisture at the wilt point of plants expressed as centimeters (cm) of water per 1 cm depth of soil:

- **very low** – 0 to 7.5 cm
- **low** 7.5 to 15 cm
- **moderate** – 15 to 22.5 cm
- **high** – 22.5 to 20 cm
- **very high** – >30 cm

Water Table High – highest level of a moisture saturated zone in the soil in most years; (H) – indicates a hydric soil, one that is typically saturated during the growing season.

Bedrock – depth under the soil surface to consolidated bedrock as expressed in meters (m); bedrock controlled areas (C) occur where the underlying bedrock is shallow (<1 m) and the rock determines or stongly influences the shape of the land even though a thin deposit of glacial till or lake sediment may be at the surface.

Shrink/Swell – potential for volume change in a soil with loss or gain in moisture content; commonly expressed in percentage change in length of an unconfined soil sample as moisture content is increased:

- **low** – <3% change in length
- **medium** – 3% to 6% change in length
- **high** – >6% change in length

Homesite Limitation – describe the impact of certain soil properties and site features on honmesites and septic tank absorption fields:

- **slight** – conditions are generally favorable for homesites and septic tank absorption fields with minor problems to overcome
- **moderate** – conditions are not favorable for homesites and septic tank absorption fields without special planning, design, or maintenance to overcome limitations
- **severe** – conditions so unfavorable or difficult to overcome that special design, significant increases in construction costs, and increased maintenance are required:
  - (B) – basement limitations; (Sl) – slippage limitations; (St) – septic tank absorption field limitations

Hazard – features of the soil or site that make its use hazardous, such as flooding, slippage, and large stones.

Data Source:

U.S. Dept. Agriculture, Soil Conservation Service and Ohio Dept. Natural Resources, Div. Soil & Water Conservation (Redmond et al. 1971, Ernst and Martin 1994, Martin and Prebonick 1994)

TABLE 3.4. ERODIBILITY OF OLD WOMAN CREEK WATERSHED SOILS

Map Symbol	Soil Series	Erosion Factor (K)	Erosion Factor (T)	Wind Erosion
Aa	Adrian	0.37	5	6
AkA	Allis	0.43	3	6
AmD2	Amanda	0.37	5	6
AnG	Amanda-Dekalb	0.37	5	6
AvA (OgA)	Avery (Ogontz)	0.43	5	3
AyB (OhB)	Avery (Ogontz)	0.37	5	6
Bc	Beaches	—	—	—
BeA	Bennington	0.43	3	6
BgA	Bennington	0.43	3	6
BgB	Bennington	0.43	3	6
BkA	Bixler	0.17	5	2
BkB	Bixler	0.17	5	2
BvG	Brecksville	0.43	4	6
CaB	Cardington	0.37	3	6
CbC2	Cardington	0.37	3	6
ChB	Chili	0.32	4	5
Cm	Colwood	0.28	5	5
Co	Condit	0.37	3	7
CtB	Conotton	0.24	3	5
CuC	Conotton	0.24	3	8
DbB	Dekalb	0.17	2	6
DbD	Dekalb	0.17	2	6
DeA	Del Rey	0.43	3	6
EnA	Elnora	0.17	4	2
EoA	Elnora	0.17	4	2
Fn	Fluvaquents	—	—	—
Fr	Fries	0.28	3	7
Gd	Gilford	0.10	4	2
HkA	Haskins	0.37	4	5
Ho	Holly	0.28	5	6
JtA	Jimtown	0.32	4	5
KbA	Kibbie	0.28	5	5
Me	Mermill	0.37	4	7
Mf	Milford	0.28	5	4
Mg	Millgrove	0.24	4	6
Mr	Miner	0.32	3	7
MxA	Mitiwanga	0.32	2	6
MxB	Mitiwanga	0.32	4	6
No	Nolin	0.43	5	5
OaB	Oakville	0.17	5	2
Op	Orrville	0.37	5	6
Or	Orrville	0.37	5	6
OsB	Oshtemo	0.24	5	3
Pc	Pewamo	0.28	5	7
Pg	Pits	—	—	—
Pk	Pits (quarry)	—	—	—
PmA	Plumbrook	0.20	5	3
RcA	Rawson	0.24	4	3
RcB	Rawson	0.24	4	3
RgA	Rimer	0.17	4	2
SbF	Saylesville	0.37	5	5

TABLE 3.4. ERODIBILITY OF OLD WOMAN CREEK WATERSHED SOILS (cont'd)

Map Symbol	Soil Series	Erosion Factor (K)	Erosion Factor (T)	Wind Erosion
ShB	Shinrock	0.37	5	6
SkC2	Shinrock	0.37	5	7
SpB	Spinks	0.17	5	2
SpD	Spinks	0.17	5	2
Tg	Tioga	0.37	5	5
TuA	Tuscola	0.24	5	3
TuB	Tuscola	0.24	5	3
Uc	Udipsamments-Spinks	—	—	—
Ud	Udorthents	—	—	—
WaB	Wakeman	0.28	2	3
WaC	Wakeman	0.28	2	3
W	Water body	—	—	—
ZuC2	Zurich	0.37	5	6
ZuD2	Zurich	0.37	5	6
ZuE2	Zurich	0.37	5	6
ZuF	Zurich	0.37	5	6

LEGEND:

Note: erosion factors and wind erosion group given for the upper 15 to 35 cm of soil.

Erosion Factor (K) – a relative index of the susceptibility of a bare, cultivated soil to particle detachment and transport by rainfall (sheet and rill erosion) adjusted to a standard 9% slope; values of K can range from 0.05 to 0.69, the higher the value the more susceptible the soil is to water erosion.

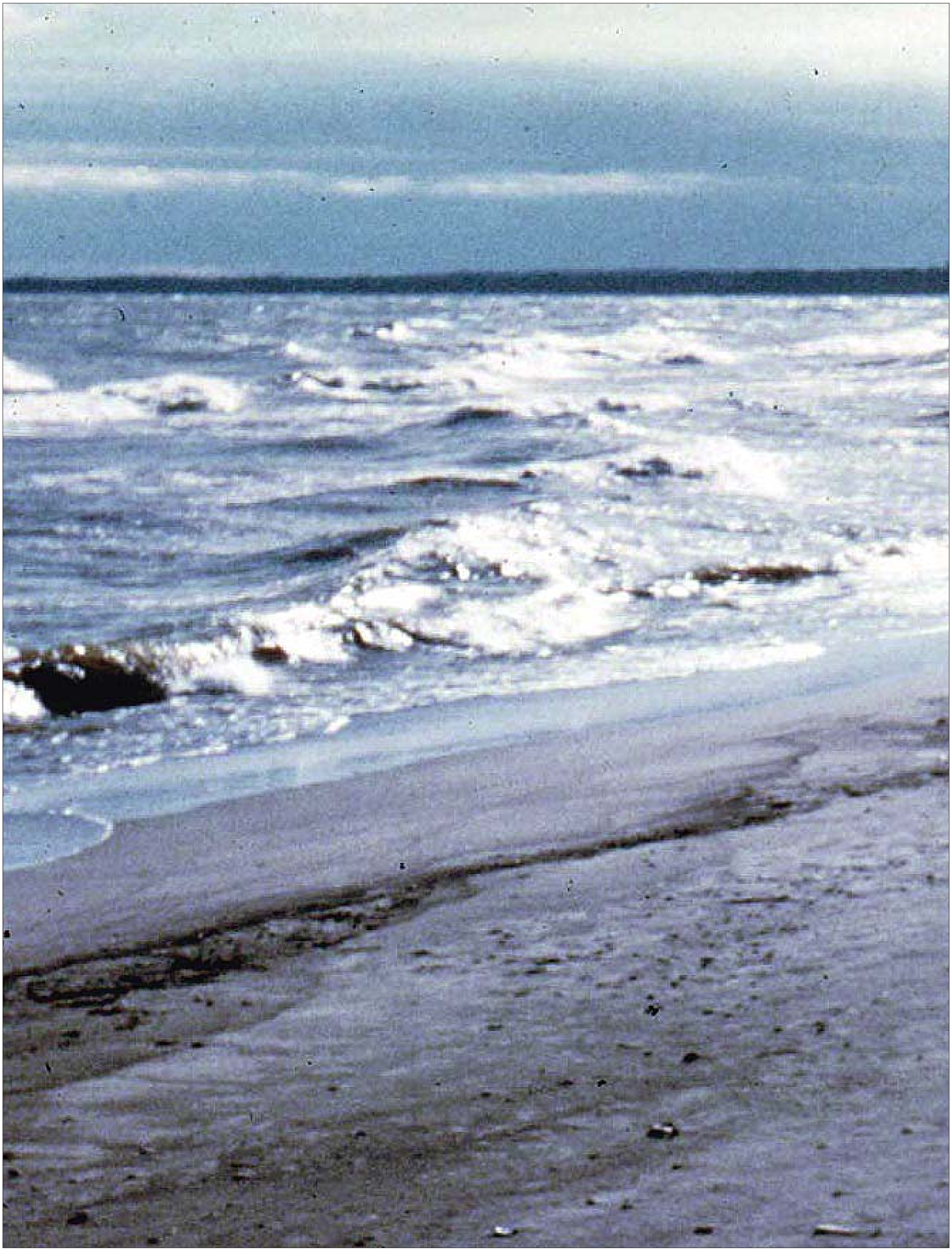
Erosion Factor (T) – an estimate of the maximum average annual rate of soil erosion by water or wind that can occur without affecting crop production of a sustained period; rate in tons per year; values of T can range from 1 to 5 tons per acre (0.4 ha) per year, with 1 ton for shallow and otherwise fragile soils and 5 tons for deep soils that are least subject to damage by erosion.

Wind Erosion Group – a set of classes (1 to 8) based on compositional properties of the surface soil that affect susceptibility to wind erosion; associated with each group is a wind erosion index in tons per acre (0.4 ha) per year based on an unsheltered, bare soil which lacks a surface crust; the higher the class (group) the more resistant the soil is to wind erosion:

- **Group 1** – coarse to very fine sands
- **Group 2** – loamy coarse to loamy very fine sands
- **Group 3** – coarse sandy loam to very fine sandy loam
- **Group 4** – clays, silty clays, clay loams, and silty clay loams; calcareous loams
- **Group 5** – non-calcareous loams and silt loams, <20% clay to sandy clay
- **Group 6** – non-calcareous loams and silt loams, >20% clay to sandy clay and <35% clay
- **Group 7** – silts and non-calcareous silty clay loams, <35% clay
- **Group 8** – soils not subject to wind erosion because of coarse fragments or surface wetness.

Data Source:

U.S. Dept. Agriculture, Soil Conservation Service and Ohio Dept. Natural Resources, Div. Soil & Water Conservation (Soil Survey Division Staff 1993, Ernst and Martin 1994, Martin and Prebonick 1994)



Waves from a northwest storm attack the barrier beach at Old Woman Creek (Charles E. Herdendorf).

Chapter 4. Climatology

Past Climate Trends

During the Pleistocene epoch, 1.6 million to 10,000 years before the present (YBP), at least four major glaciers advanced over the Great Lakes. Ice more than 2 km thick slowly proceeded across the landscape, scouring the surface, filling valleys, and leveling hills. The last glacier (Wisconsin) reached as far south as Cincinnati (18,000 YBP) before it began to recede (Forsyth 1961). The air temperatures ahead of the glacier were probably 10°C cooler than at present (Figure 4.1) as spruce forests extended into Florida and Texas (Terasmae 1961). As the glacier receded to the northeast, reaching present-day Niagara Falls about 12,500 YBP, a relatively dry tundra climate dominated northern Ohio in its wake (Beltzner 1976). As the temperature slowly warmed and moisture increased, conifer forests became more prevalent as shown by spruce pollen frequencies in excess of 50% (Shane 1994).

By 10,000 YBP the ice sheet had retreated north of the modern Great Lakes and air temperatures in northern Ohio had risen to only 3-4°C lower than at present (Phillips 1989). Gradually at first, then more rapidly, spruce and other conifers were replaced by oak and other deciduous trees. The first evidence of human occupation in the watershed is from this period as nomadic Palaeo-Indians hunted in Old Woman Creek valley (Shane 1981). Lake Erie's water level was about 20-25 m lower than present leaving the central basin partially dry (Herdendorf and Bailey 1989) and the estuary, if one existed, was some 50 km farther to the northeast.

The climate continued to warm after 10,000 YBP with air temperatures in the Great Lakes region taking a dramatic jump of 4-5°C within a millennium (Figure 4.2). Pollen studies show that spruce was entirely replaced by hardwood trees (Cushing 1965, Shane 1994), as boreal forests and tundra gave way to deciduous woodlands and prairie grasslands. A warmer climate also favored a more diverse fauna, including the propagation of game animals along the valleys of north central Ohio, as Early Archaic Indians established hunting camps on the bluffs near Old Woman Creek around 8,000 YBP (Shane 1992, Abel 1994).

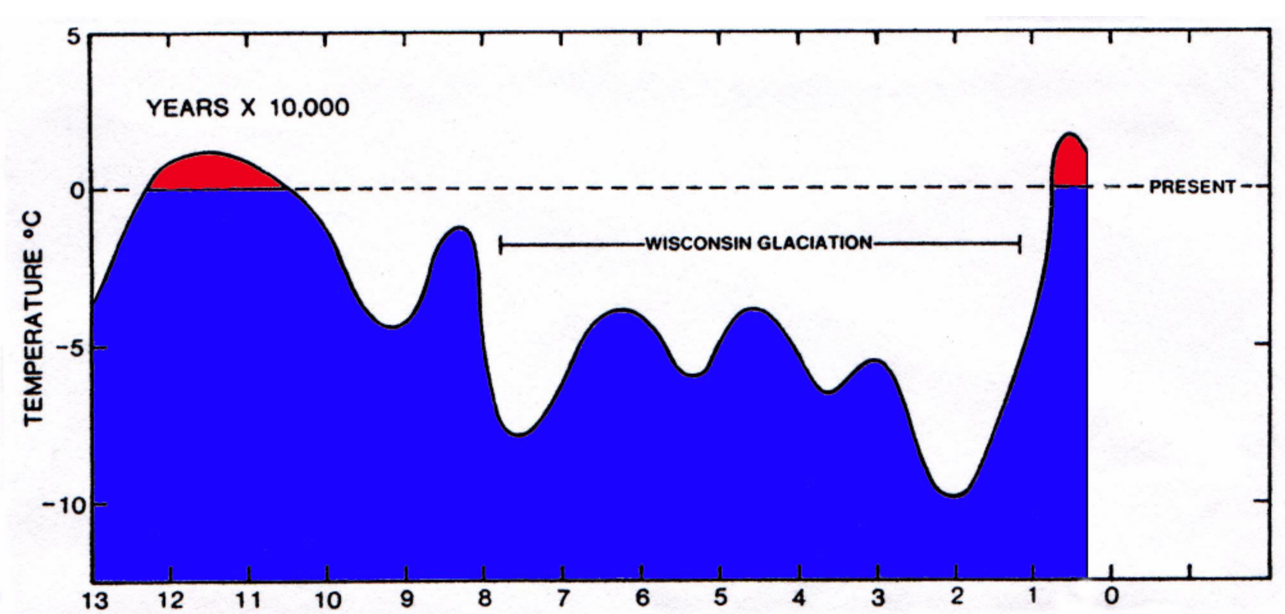


Figure 4.1. Trends in mean air temperature in the Great Lakes Basin during the Wisconsinan glacial period: 100,000 to 10,000 YBP (from Terasmae 1961, Phillips 1989).

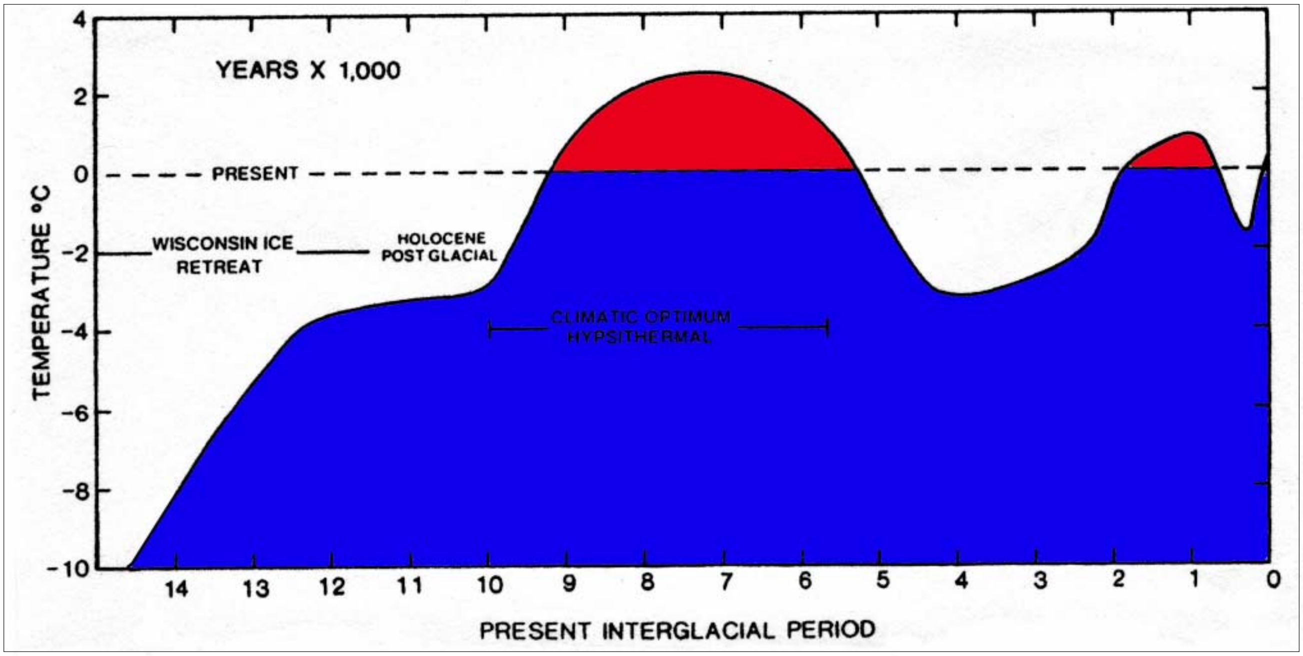


Figure 4.2. Trends in mean air temperature in the Great Lakes Basin during the present interglacial period: 14,000 to 0 YBP (from Terasmae 1961, Phillips 1989).

As the ice moved farther north, the prevailing winds shifted from off the ice front to more westerly and dryer air masses, as warmer weather spread across the region (Webb and Bryson 1972). Between 8,000 to 6,000 YBP the region was quite mild, perhaps 2-3°C warmer than at present, initiating a phase known as the Climatic Optimum or Hypsithermal Interval (Phillips 1989). Pollen records indicate that subtropical plants grew as far north as Minnesota during this interval (Ross 1995). Following the onset of the warm phase, conditions became somewhat dryer (Figure 4.3) and drought-resistant (prairie) vegetation moved into the region from the southwest.

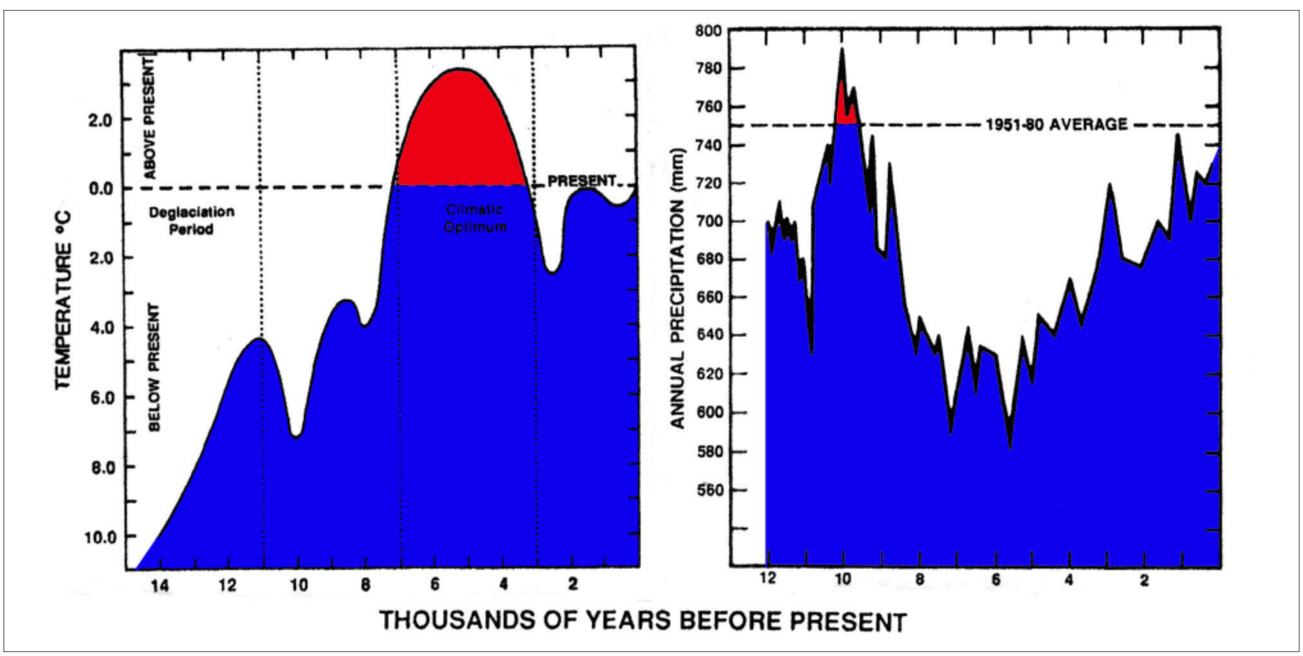


Figure 4.3. Postglacial trends in mean air temperature and precipitation in the Great Lakes Basin: 14,000 to 0 YBP (from Terasmae 1961, Webb 1981, Phillips 1989).

Starting about 5,500 YBP there was another rapid change in climate as the mean temperature dropped nearly 5°C in 1,500 years. This cooler period, known as Neoglaciation (Flint 1971), was accompanied by the growth of polar glaciers and a return of conifer trees to north central Ohio (Reeder and Eisner 1994). Historical evidence points to a cool, but warming period from about 3,000 to 1,500 years BP. Woodland Indian cultures flourished during this period, establishing agrarian villages on promontories in northern Ohio, including a bluff overlooking Old Woman Creek estuary (Shane 1981). By this time Lake Erie had risen to a level that flooded the valley of Old Woman Creek, forming an estuary near its present location, as shown by pollen records for aquatic and wetland plants (Reeder and Eisner 1994).

Beginning around 1,200 YBP, a 500-year mild phase (Medieval Period, AD 800 to 1,300) ensued (Figure 4.4) with temperatures 1°C warmer than present (Phillips 1989). The Whittlesey (Erie) Indians inhabited northern Ohio during the mild phase, constructing small, fortified villages on high banks of streams that empty into Lake Erie (Brose 1976, Otto 1980). Swain (1984) speculated that near the end of the Medieval mild climate, the first European settlement in the region may have taken place when a Norse expedition traversed the length of the Great Lakes (ca. 1362), leaving an inscription on the controversial Kensington Runestone in northeastern Minnesota.

In the later part of the 14th century (700 YBP), the climate swung back toward progressively colder, wetter conditions (Figure 4.4). Another Neoglaciation episode occurred from AD 1430 to 1850 that is sometimes called the "Little Ice Age" (Ross 1995). At this time the glaciers in northern Canada made a modest advance and Ohio became considerably colder. Presumably in response to adverse climatic conditions and hostilities among Indian groups, most of the State was without inhabitants from the 15th to 18th centuries, except for small settlements of Whittlesey Indians along the Lake Erie shore and Fort Ancient Indian villages in the Ohio River valley, where these water bodies moderated the climate (Otto 1979, 1980).

European settlement of the Great Lakes region began in appreciable numbers by the middle of the 18th century. Summers were still cool during the first half of the 19th century, in particular 1816 has been called the "year without a summer" because frosts occurred each month (volcanic ash from the eruption of Mount Tambora on the island of Sumbawa in Indonesia appears to be associated with this climatic event). Following the cold episode, until about 1940, temperatures warmed somewhat, followed by another period of lower temperatures (Figure 4.5). In recent years there has been another warming trend which may be related, in part, to the "greenhouse effect"–the warming of the Earth's atmosphere because of its transparency to incoming sunlight and its opacity to heat radiated from Earth. Opacity, hence heat, is increased by added amounts of carbon dioxide, water vapor, methane, and dust in the atmosphere.

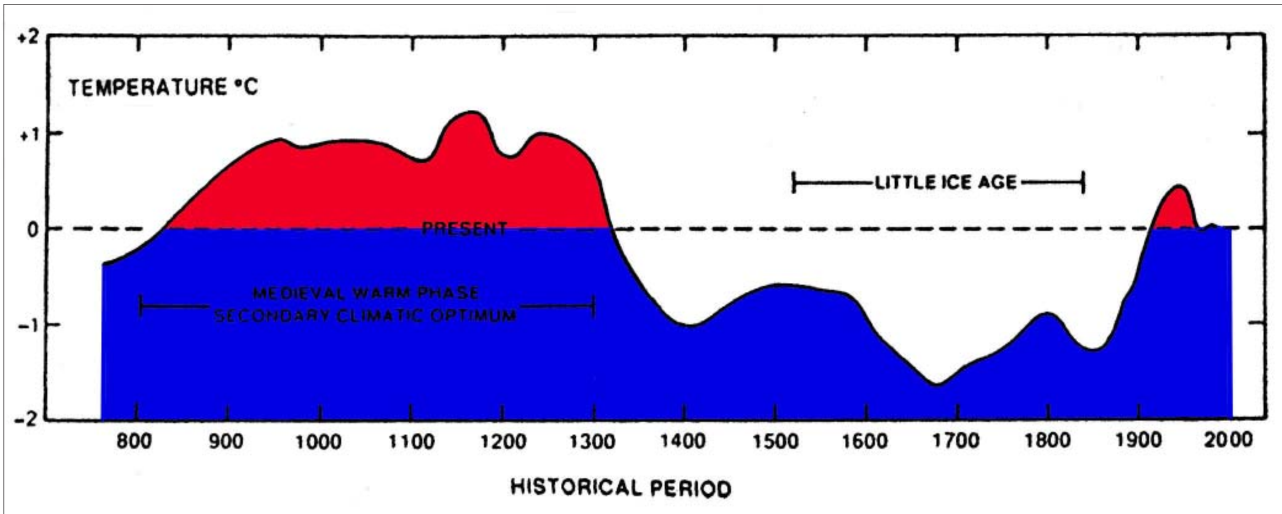


Figure 4.4. Historic trends in mean air temperature in the Great Lakes Basin: 1,200 to 0 YBP (from Phillips 1989).

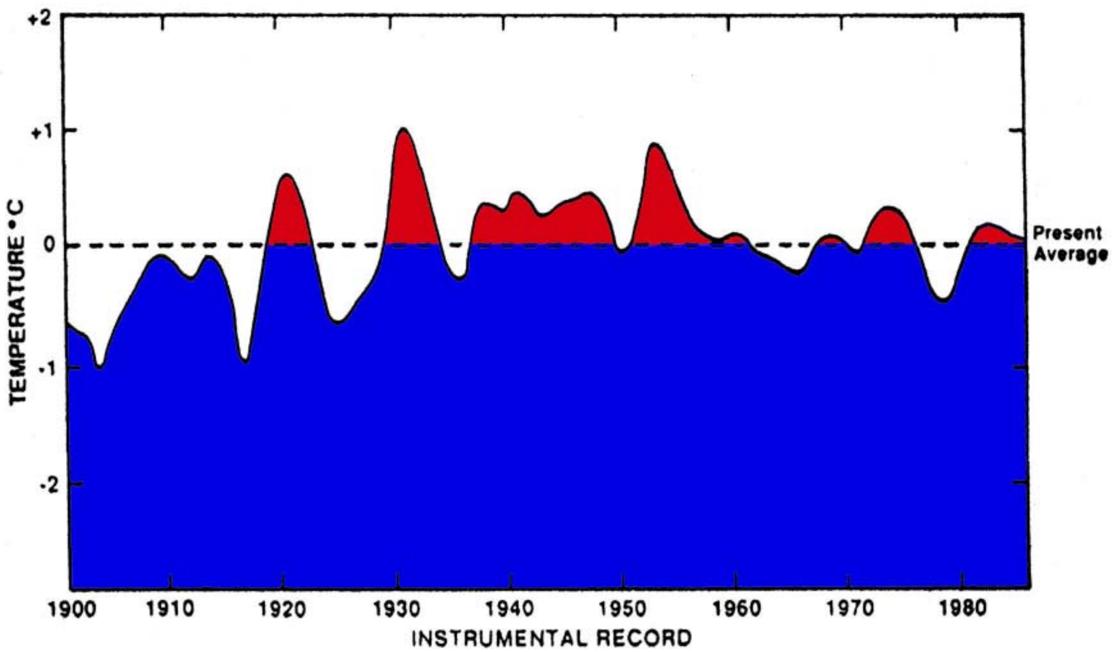


Figure 4.5. Historic trends in mean air temperature in the Great Lakes Basin during the period of instrumental record: 100 to 20 YBP (from Phillips 1989).

MODERN CLIMATE

The climate of north central Ohio is classified as "temperate – humid continental – long summer" (Fisher 1989), signifying a middle latitude location (35°-45°) in the interior of a large land mass well removed from oceanic influences with ample rainfall, warm to hot summers, and cold winters. These climatic characteristics are expressed in four distinct seasons, large seasonal temperature ranges, frequent precipitation, and sudden changeability with the rapid passage of different weather systems through the area. While the prevailing winds are from the southwest, one or two weather disturbances affect the Old Woman Creek watershed each week, bringing changes in wind direction, overcast skies, and often precipitation. The settled weather associated with high-pressure systems is thus interrupted every few days by disturbances such as fronts or low-pressure areas which can bring warm subtropical air from the south or cold Arctic air from the north (Schmidlin 1996).

Thus, the climate of the watershed is marked by large fluctuations in temperature and precipitation. Because of the proximity to the lake, winds from the northerly quadrants tend to lower daily temperatures in the summer, while raising them in the winter. The growing season at the Reserve averages 198 days (frostless days). Summers are moderately warm and humid with about 16 days where the temperature exceeds 32°C (90°F). Winters are generally cold and cloudy, however, the tempering effect of the lake limits subzero (F°) temperatures on the average to only 3 out of 5 years. As is typical for continental climates, precipitation is highly variable on a yearly basis, but in the watershed it is generally abundant and evenly distributed with autumn being the driest season. Average annual precipitation is approximately 89 cm (35 in). Winds average 10 km/hr (7 knots) in the summer and 14 km/hr (10 knots) in the winter. Although the prevailing winds are southwesterly, the southern coast of Lake Erie has a history of severe storms from the northeast and northwest that have caused extensive damage to and recession of the shoreline (Carter and Guy 1980). Average monthly weather conditions for Erie county, Ohio are tabulated in Table 4.1. Monthly average precipitation and maximum/minimum average daily air temperatures for Sandusky, Ohio (18 km WNW of the Reserve) are given in Table 4.2.

TABLE 4.1. AVERAGE WEATHER CONDITIONS FOR ERIE COUNTY, OHIO

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DAYS												
Sunny	10	10	12	14	17	18	21	20	18	17	10	9
Rainy	5	5	6	7	7	6	5	5	5	5	4	5
Thunderstorm	0	0	1	2	5	7	7	5	3	1	0	0
Snowy (> 2.5 cm)	3	2	2	0	0	0	0	0	0	0	1	2
Hot (> 32°C)	0	0	0	0	5	6	5	3	0	0	0	0
Cold (< 0°C)	27	23	20	-	0	0	0	0	0	-	13	23
WIND												
Speed (km/hr)	15	15	18	15	13	11	11	9	11	13	15	15
Direction (dominant)	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
Gusts (days)	4	4	5	5	3	3	2	1	2	3	4	5
LAKE												
Temperature (°C)	< 1	< 1	2	6	13	19	22	24	21	14	7	2
Ice thickness (cm)	20	30	10	0	0	0	0	0	0	0	0	5
SUNSHINE												
Percent (%) (of possible)	32	38	44	51	60	68	70	65	63	58	39	34
Clouds (% sky)	80	80	70	70	60	60	50	50	60	60	80	80
AIR TEMPERATURE	> Probability (%)											
-5°C	82	86	100	100	100	100	100	100	100	100	100	96
0°C	26	26	93	100	100	100	100	100	100	100	100	53
5°C	0	0	15	100	100	100	100	100	100	100	69	0
10°C	0	0	0	44	100	100	100	100	100	100	0	0
15°C	0	0	0	0	59	100	100	100	100	15	0	0
20°C	0	0	0	0	0	89	100	100	26	0	0	0
25°C	0	0	0	0	0	0	11	11	0	0	0	0

> = greater than
< = less than

Period of Record: 1859-1985

Data Sources: Alexander (1924), Miller (1971), Herdendorf et al. (1986a,b), Herdendorf (1987), Bolsenga and Herdendorf (1993)

TABLE 4.2. WEATHER DATA FOR SANDUSKY, OHIO

	Average Daily Air Temperature (°C)			Precipitation (cm)	
	Minimum	Maximum		Average	Snowfall
JAN	-6.1	1.1		6.1	18.3
FEB	-5.6	2.2		5.6	16.0
MAR	-1.1	7.2		7.3	14.7
APR	4.4	13.9		8.2	2.8
MAY	10.6	21.1		8.7	0.0
JUN	16.1	26.1		10.4	0.0
JUL	18.3	28.3		9.2	0.0
AUG	17.8	27.8		8.2	0.0
SEP	13.9	23.9		7.1	0.0
OCT	8.3	18.3		5.1	0.0
NOV	1.7	10.0		5.6	6.4
DEC	-3.9	3.3		5.2	15.5
YEAR MEAN	6.2	15.3	TOTAL	86.7	73.7

Period of Record: 1936-1965

Data Source: U.S. Weather Service, Sandusky, Ohio

Starting in 1983, meteorological observations have been recorded at the Old Woman Creek State Nature Preserve and National Estuarine Research Reserve (Figure 4.6). Parameters routinely monitored include: (1) air temperature, (2) precipitation, and (3) wind speed and direction. Summaries of these observations are presented in Tables 4.3 through 4.7. Starting in 1997, photosynthetically active radiation (PAR) measurements have been recorded at the Reserve. PAR measurements are discussed in the Solar Radiation section of this chapter. Complete meteorological records are available at the Ohio Center for Coastal Wetlands Study located within the Old Woman Creek State Nature Preserve and National Estuarine Research Reserve. A related daily observation is the open or closed condition of the Lake Erie barrier beach at the mouth of the estuary. Monthly summaries of barrier beach conditions for the period 1983 to 2000 are presented in the Estuary Hydrology section in Chapter 5.

Figure 4.6. Meteorological tower and weather station at Old Woman Creek SNP & NERR (Charles E. Herdendorf).

TABLE 4.3 MONTHLY AIR TEMPERATURE AT OLD WOMAN CREEK NERR 1989-2000

Maximum and Minimum (°C)

	1989		1990		1991		1992		1993		1994	
MONTH	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
JAN	—	—	13.89	-4.44	11.67	-12.78	12.78	-16.11	15.00	-7.78	9.44	-23.33
FEB	—	—	17.78	-13.89	17.78	-13.33	14.44	-11.67	12.22	-15.56	18.89	-13.89
MAR	—	—	25.00	-9.44	21.67	-17.39	18.89	-7.22	15.00	-11.67	24.44	-3.89
APR	—	—	30.56	-3.89	31.11	-3.33	26.67	-2.78	27.22	1.11	30.56	-1.67
MAY	—	—	25.56	3.89	32.78	5.56	30.00	2.22	31.67	6.11	31.11	4.44
JUN	—	—	31.67	5.00	32.22	9.44	31.67	6.11	32.78	9.44	35.00	7.78
JUL	—	—	31.67	10.00	35.00	12.22	31.11	11.11	36.67	13.33	34.44	12.78
AUG	—	—	33.33	11.67	31.67	11.11	32.78	9.44	36.11	12.22	30.00	10.56
SEP	25.56	3.89	31.67	4.44	33.89	2.22	29.44	4.44	32.78	5.56	31.11	8.89
OCT	28.33	1.11	27.22	0.00	27.22	-1.11	25.00	0.00	28.33	0.56	26.67	2.78
NOV	21.11	-6.11	22.22	-3.33	20.00	-7.78	19.44	-3.33	18.89	-1.67	21.11	-2.78
DEC	7.78	-23.89	15.00	-12.78	17.22	-9.44	15.00	-7.78	15.00	-13.89	16.67	-6.67
MEAN	—	—	25.46	-1.06	26.02	-2.05	23.94	-1.30	25.14	-0.19	25.79	-0.42

	1995		1996		1997		1998		1999		2000	
MONTH	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
JAN	19.44	-11.67	—	—	18.89	-13.89	17.49	-6.95	19.00	-19.36	16.38	-20.56
FEB	12.22	-14.44	—	—	20.85	-12.26	17.46	-6.67	22.72	-9.01	24.12	-13.87
MAR	26.11	-6.11	—	—	22.58	-7.42	28.01	-8.72	23.81	-15.74	26.91	-6.03
APR	28.89	-2.78	—	—	24.62	-5.37	23.76	-0.99	26.56	-2.15	25.01	-2.10
MAY	31.11	8.89	—	—	24.88	1.72	32.29	8.53	31.59	2.24	31.21	4.36
JUN	35.56	13.33	—	—	33.97	6.73	34.67	8.22	34.34	7.64	32.44	6.80
JUL	37.78	13.89	—	—	33.79	11.59	33.98	13.27	36.06	12.80	30.31	9.52
AUG	—	—	35.00	14.44	32.17	11.87	31.63	11.08	32.02	12.46	31.79	9.59
SEP	—	—	—	—	30.07	5.81	33.65	9.12	32.49	6.00	30.31	4.16
OCT	—	—	—	—	29.33	-0.77	28.57	1.06	26.73	0.90	28.03	1.52
NOV	—	—	23.33	-2.78	12.05	-6.58	22.23	-2.23	25.20	-3.39	22.45	-11.42
DEC	—	—	17.78	-6.11	11.61	-10.85	21.83	-13.27	17.48	-12.47	10.00	-18.20
MEAN	—	—	—	—	24.57	-1.62	27.13	1.04	27.33	-1.67	25.75	-3.02

TABLE 4.4. MONTHLY PRECIPITATION AT OLD WOMAN CREEK NERR 1983-2000

Monthly Total (cm)

MONTH	1983	1984	1985	1986	1988	1989	1990	1991	1992
JAN	—	—	—	—	—	4.80	3.56	4.50	4.70
FEB	—	—	—	—	—	1.73	9.35	4.57	3.94
MAR	—	—	—	—	—	4.98	2.44	3.07	5.28
APR	—	8.46	3.51	8.74	3.86	6.86	7.52	7.29	8.38
MAY	—	11.23	10.90	9.40	1.96	12.83	10.08	6.96	6.65
JUN	—	5.26	5.13	7.80	1.42	6.71	5.79	1.37	5.72
JUL	—	7.62	7.04	9.04	6.91	7.65	9.19	3.00	24.46
AUG	—	7.26	9.55	5.66	10.21	3.53	6.76	4.29	12.98
SEP	—	6.65	2.34	12.32	2.79	8.13	14.76	3.91	13.03
OCT	—	9.27	8.33	7.67	7.16	8.76	7.87	8.43	3.76
NOV	—	7.21	15.06	4.55	8.74	7.14	4.24	5.84	4.10
DEC	6.65	5.72	—	—	4.80	2.67	15.95	4.17	7.67
TOTAL	—	—	—	—	—	75.79	97.51	57.40	100.67

MONTH	1993	1994	1995	1996	1997	1998	1999	2000	MEAN
JAN	8.31	4.72	8.79	3.51	4.80	—	6.35	2.46	5.14
FEB	4.04	1.37	2.57	3.61	11.00	—	3.18	2.54	4.35
MAR	7.80	2.54	4.42	5.82	11.96	—	3.96	0.81	4.83
APR	8.56	9.78	11.25	10.52	—	—	10.87	5.36	7.93
MAY	2.79	3.86	10.59	6.50	25.12	2.03	3.28	11.71	8.44
JUN	10.31	9.53	11.46	10.72	14.99	11.86	12.07	12.29	8.28
JUL	2.79	4.57	8.00	10.82	—	—	7.72	6.48	8.24
AUG	2.44	10.49	11.07	0.08	—	6.93	4.04	6.43	6.78
SEP	10.03	3.45	3.56	24.18	—	3.73	5.87	6.12	7.79
OCT	5.61	1.45	9.14	7.49	—	3.89	6.99	3.94	6.65
NOV	9.98	5.72	6.93	5.51	—	3.05	6.68	1.24	7.07
DEC	4.06	7.57	1.88	8.61	—	3.56	5.51	4.04	5.92
TOTAL	76.72	65.05	89.66	97.37	—	—	76.52	63.42	81.42

Note: Weather station inoperable in 1987

TABLE 4.5. MONTHLY RAINSTORMS AT OLD WOMAN CREEK NERR 1983-2000

Number of Storms (>2.0 cm) and Storm Precipitation (cm)

MONTH	1983	1984	1985	1986	1988	1989	1990	1991	1992
JAN	—	—	1	—	—	1	0	0	1
Precip	—	—	2.01	—	—	2.41	0	0	2.29
FEB	—	1	—	—	—	0	2	1	0
Precip	—	2.67	—	—	—	0	6.60	2.54	0
MAR	—	1	2	—	—	0	0	0	0
Precip	—	4.06	6.30	—	—	0	0	0	0
APR	—	2	0	1	1	1	1	1	2
Precip	—	5.38	0	4.22	2.21	2.31	3.66	2.90	5.11
MAY	—	1	2	3	0	2	1	1	1
Precip	—	3.48	6.53	7.98	0	4.93	3.48	4.32	2.84
JUN	—	1	0	1	0	2	0	0	1
Precip	—	3.30	0	5.44	0	4.22	0	0	3.71
JUL	—	2	0	1	2	1	2	0	4
Precip	—	5.26	0	4.06	4.42	3.56	6.78	0	18.34
AUG	—	2	1	0	2	0	1	0	3
Precip	—	5.18	3.35	0	5.97	0	3.63	0	7.62
SEP	—	0	0	2	1	2	3	0	3
Precip	—	0	0	7.62	2.36	4.88	10.31	0	10.41
OCT	—	1	2	2	1	2	1	1	0
Precip	—	5.38	6.10	5.21	5.13	7.19	2.46	3.45	0
NOV	1	1	2	0	2	1	0	1	3
Precip	2.16	2.18	7.09	0	5.23	3.33	0	2.79	12.47
DEC	1	0	1	1	1	0	3	1	1
Precip	2.41	0	2.84	2.29	3.10	0	10.72	2.08	5.51
TOTAL						12	14	6	19
Precip						32.83	47.64	18.08	68.30
STORMS (percent of total monthly rainfall)						43.3%	48.8%	31.5%	61.7%

Note: Weather station inoperable in 1987

TABLE 4.5. MONTHLY RAINSTORMS AT OLD WOMAN CREEK NERR 1983-2000 (cont'd)

Number of Storms (>2.0 cm) and Storm Precipitation (cm)

MONTH	1993	1994	1995	1996	1997	1998	1999	2000	MEAN
JAN	1	1	2	0	0	—	1	0	0.7
Precip	4.57	2.08	6.81	0	0	—	3.35	0	2.94
FEB	0	0	0	1	1	—	0	0	0.5
Precip	0	0	0	2.79	7.90	—	0	0	3.75
MAR	3	0	1	0	2	—	1	0	0.8
Precip	6.53	0	2.90	0	5.28	—	2.00	0	2.71
APR	1	2	2	1	1	2	2	1	1.3
Precip	4.83	8.15	4.52	3.76	5.41	5.72	3.76	3.08	4.90
MAY	0	1	3	1	5	0	1	3	1.6
Precip	0	2.00	8.00	3.33	20.07	0	2.57	9.65	2.85
JUN	2	3	3	3	3	3	2	2	1.6
Precip	7.82	7.57	10.82	8.33	12.07	8.76	9.30	6.12	3.36
JUL	0	0	1	2	1	0	2	1	1.2
Precip	0	0	5.18	7.59	4.83	0	7.42	3.02	3.71
AUG	0	3	2	0	—	1	0	1	1.1
Precip	0	9.17	8.69	0	—	5.72	0	5.23	3.41
SEP	1	0	0	5	—	1	1	1	1.3
Precip	3.84	0	0	21.49	—	2.87	4.27	3.86	3.60
OCT	1	0	2	1	—	0	1	1	1.1
Precip	2.31	0	7.09	3.91	—	0	2.57	3.23	3.38
NOV	3	1	1	1	—	1	1	0	1.2
Precip	8.38	2.44	2.72	2.74	—	2.06	2.06	0	2.92
DEC	1	2	0	2	—	1	1	0	1.1
Precip	2.36	4.70	0	5.92	—	2.64	2.03	2.16	2.87
TOTAL	13	13	17	17			13	10	14
Precip	40.64	32.11	56.73	59.86			39.33	36.35	40.40
STORMS (percent of total monthly rainfall)	53.0%	55.5%	63.3%	61.5%	—	—	51.4%	57.3%	49.6%

TABLE 4.6. MONTHLY AVERAGE WIND SPEED AND DIRECTION AT OLD WOMAN CREEK NERR 1997-2000

MONTH	WS 1997	WD 1997	WS 1998	WD 1998	WS 1999	WD 1999	WS 2000	WD 2000	WS MEAN	WD MEAN
JAN	3.5	220°	8.5	190°	2.8	194°	2.9	208°	4.4	203°
FEB	8.0	204°	8.4	136°	2.7	190°	2.4	213°	5.4	186°
MAR	12.0	175°	3.3	192°	2.9	183°	2.8	174°	5.2	181°
APR	9.0	193°	3.1	122°	3.3	149°	2.6	151°	4.0	154°
MAY	10.7	194°	2.0	144°	2.3	141°	2.2	177°	4.3	132°
JUN	7.4	145°	1.7	186°	1.7	151°	2.0	180°	3.2	166°
JUL	6.4	171°	1.7	192°	1.5	198°	1.6	164°	2.8	181°
AUG	6.0	154°	1.5	161°	1.8	163°	1.6	186°	2.5	166°
SEP	6.4	189°	1.8	211°	1.8	183°	2.1	159°	3.0	186°
OCT	6.8	200°	1.9	205°	2.3	200°	1.7	178°	3.2	196°
NOV	8.7	190°	2.8	207°	2.7	231°	2.4	193°	4.2	205°
DEC	9.4	224°	2.6	216°	2.6	206°	2.5	207°	4.3	213°
MEAN	7.9	188°	3.3	180°	2.4	182°	2.2	182°	3.9	181°

Wind Speed (WS) reported in m/sec
Wind Direction (WD) reported in true degrees (°) from which the wind emanated

TABLE 4.7. MONTHLY MAXIMUM AND MINIMUM WIND SPEED AT OLD WOMAN CREEK NERR 1997-2000

MONTH	MAX 1997	MIN 1997	MAX 1998	MIN 1998	MAX 1999	MIN 1999	MAX 2000	MIN 2000	MAX MEAN	MIN MEAN
JAN	6.5	1.7	18.3	2.8	5.8	0.2	5.7	1.5	9.1	1.6
FEB	17.6	0.7	29.4	1.3	5.3	0.7	4.7	0.7	14.3	0.9
MAR	22.7	6.5	8.1	1.0	5.2	1.3	5.6	1.1	10.4	2.5
APR	20.6	4.3	7.8	1.2	6.9	1.2	6.2	1.0	10.4	1.9
MAY	21.8	5.6	4.8	0.9	6.4	1.0	4.8	1.2	9.5	2.2
JUN	26.7	3.5	3.5	1.0	3.1	1.0	4.4	1.0	9.4	1.6
JUL	14.3	3.8	3.1	0.8	2.8	0.7	3.2	0.7	5.9	1.5
AUG	16.0	1.8	3.3	0.7	4.2	0.8	3.0	0.8	6.6	1.0
SEP	16.9	2.5	4.2	0.9	4.7	1.0	5.5	0.8	7.8	1.3
OCT	14.7	2.3	3.0	0.9	4.5	0.5	4.6	0.5	6.7	1.1
NOV	17.4	1.9	6.0	0.6	6.3	0.8	5.3	0.9	8.8	1.1
DEC	18.6	3.3	4.2	1.2	4.9	1.0	5.3	0.8	8.3	1.6
MEAN	17.8	3.2	8.0	1.1	5.0	0.9	4.9	0.9	9.0	1.5

Wind Speed (WS) reported in m/sec

LAKE EFFECT

Lake Erie has a modifying effect on the weather in the Old Woman Creek watershed and particularly on the weather in the Reserve. Winds off the lake tend to lower the air temperatures on summer days and raise them on winter days. The daily variation in air temperature becomes greater with increasing distance from the lake and the average annual precipitation increases slightly. Compared with the lakeshore, the southernmost part of the watershed has an average daily maximum 0.8°C higher, an average daily minimum 2.2°C lower, and average annual precipitation that is about 2.7 cm greater (Miller 1971). The insert below and Table 4.8 show that the frost period (interval between the first freezing date in the fall and the last freezing date in the spring) increases as the distance from the lake increases. This yields a longer growing season in the vicinity of the estuary than in the southern part of the watershed. The frost-free period for communities in the vicinity of the watershed range from 154 to 198 days.

	Growing Season
Huron (on Lake Erie)	198 days
Berlin Heights (6 km south of Lake Erie)	168 days
Norwalk (17 km south of Lake Erie)	154 days

Because water has a higher specific heat (capacity to absorb thermal energy in relation to temperature change) than soil, Lake Erie changes temperature more slowly than the surface of the watershed, delaying the change of seasons along the shore. Lake Erie absorbs a great amount of heat in the spring and summer with a relatively small change in temperature and slowly releases that heat in the fall and winter. The heat capacity of water not only permits the lake and estuary to act as a buffer against wide fluctuations in the coastal environment, it narrows the range of temperatures to which an aquatic organism is subjected as compared to those organisms living on land. Lake temperatures rarely exceed 27°C, whereas air temperatures as high as 42°C have been recorded in the vicinity of the watershed.

As the lake and estuary water gradually warm in the spring, the land within about 5 km of the shore remains cooler than the more southerly portions of the watershed. After reaching a temperature of 24-27°C in August, the lake begins to cool slowly during autumn and early winter, tempering the first cold waves of winter and pushing back the first freeze by several weeks. Lake Erie also adds moisture to the air during the cooling period. Evaporation of lake water is greatest at this time because the water is much warmer than the air. The added moisture results in frequent cloudiness; sunny days usually occur less than 20% of the time in November (Herdendorf et al. 1986a,b). To a lesser extent than it occurs in northeastern Ohio, but still noteworthy, the moisture evaporated from Lake Erie by cold air masses results in “lake-effect” rain and snow in the watershed, particularly as the cold, moist air masses ascend over the Berea escarpment.

Lake Erie is large enough to induce lake-land breezes. During the day in summer, the lake is typically cooler than the surrounding shore, and a breeze blows onshore to replace rising air masses over the warmer land. The effect of these cooling breezes can extend 30 km inland (Burns 1985). At night the lake temperature remains fairly constant while the land quickly cools, and the direction of the breeze changes and blows off the land to replace air masses rising over the lake. This process causes downdrafts of air over the lake during the day which tend to disperse clouds in front of a shoreward moving lake breeze front, resulting in clear skies over the lake and shore for 30-50% of the days in summer (Eichenlaub 1979). Conversely, at night updrafts over the lake can lead to severe thunderstorms (Phillips and McCulloch 1972).

WIND

Southwesterly winds prevail over the watershed in all months of the years, a feature common to temperate regions of the northern hemisphere. In fall and winter, northwesterly winds can also occur frequently, reaching velocities of 65 to 80 km/hr during severe storms (Herdendorf 1987). In spring, winds from the northeast are common, with storms producing velocities of 50 to 65 km/hr. The U.S. Nuclear Regulatory Commission (Ohio Edison Company 1977) reported meteorological data from a tower located near Berlin Heights. For the period 1973 to 1975 the predominant wind direction at three levels on the tower (10 m, 55 m, and 150 m) was south southwest through west southwest (37% of the time). The frequency of calm wind was 1.2% (Figure 4.7) of the time at the 10-m level and 0.1% at the upper two levels.

Wind blowing over land generally has a lower velocity than wind blowing over open Lake Erie. This

TABLE 4.8. PROBABILITY OF FREEZING AIR TEMPERATURES IN OLD WOMAN CREEK WATERSHED

Spring Season

DISTANCE SOUTH OF LAKE ERIE	PROBABILITY LATER THAN	AIR TEMPERATURE -7°C	0°C	+2°C
0-5 km	50% (5 years in 10)	Mar 13	Apr 14	Apr 25
	10% (1 year in 10)	Mar 28	Apr 24	May 7
5-10 km	50% (5 years in 10)	Mar 25	Apr 27	May 14
	10% (1 year in 10)	Apr 9	May 18	Jun 2
> 10 km	50% (5 years in 10)	Mar 25	May 6	May 20
	10% (1 year in 10)	Apr 12	May 21	Jun 4

Fall Season

DISTANCE SOUTH OF LAKE ERIE	PROBABILITY EARLIER THAN	AIR TEMPERATURE -7°C	0°C	+2°C
0-5 km	50% (5 years in 10)	Nov 30	Oct 29	Oct 18
	10% (1 year in 10)	Nov 16	Oct 18	Oct 3
5-10 km	50% (5 years in 10)	Nov 28	Oct 13	Oct 5
	10% (1 year in 10)	Nov 16	Sep 29	Sep 20
> 10 km	50% (5 years in 10)	Nov 13	Oct 8	Sep 24
	10% (1 year in 10)	–	Sep 23	Sep 5

Fall to Spring Frost Period (Days)

DISTANCE SOUTH OF LAKE ERIE	PROBABILITY GREATER THAN	AIR TEMPERATURE -7°C	0°C	+2°C
0-5 km	25% (1 year in 4)	104	168	190
	1% (1 year in 100)	133	189	217
5-10 km	25% (1 year in 4)	118	197	222
	1% (1 year in 100)	145	232	239
> 10 km	25% (1 year at 4)	133	211	239
	1% (1 year in 100)	–	241	269

Data Source: U.S. Weather Service (Miller 1971) difference is caused by greater frictional drag over land. This difference is greatest in the cooler months when the temperature differential between air and water is greatest (Table 4.9). Richards and Phillips (1970) found that on average the air to lake ratio was 1:1.66 (i.e. a 10 km/hr wind over land would have a velocity of 16.6 km/hr over the lake). Winds measured at the Research Reserve, about 0.7 km south of the lakeshore, are shown on Figure 4.8.

Thunderstorms typically occur in the watershed on 30 to 40 days each year. Tornadoes within an 80-km radius of the Reserve, for the period 1953 to 1974, were reported 85 times for a mean frequency of 3.9 per year. The most devastating tornado to hit the area was in 1924, when extensive damage and loss of life occurred in Sandusky and Lorain, Ohio, communities within a 40-km radius of the Reserve.

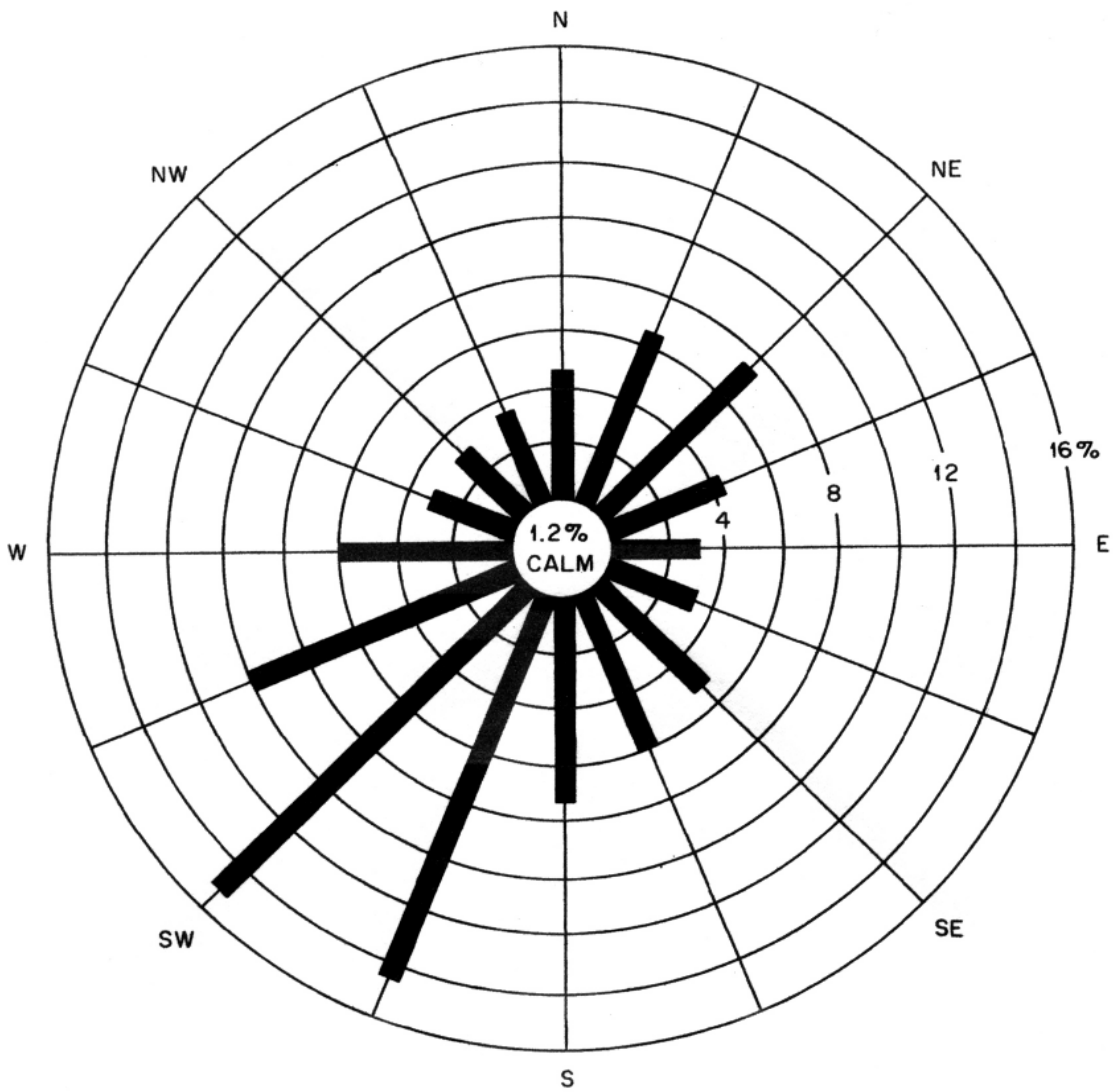
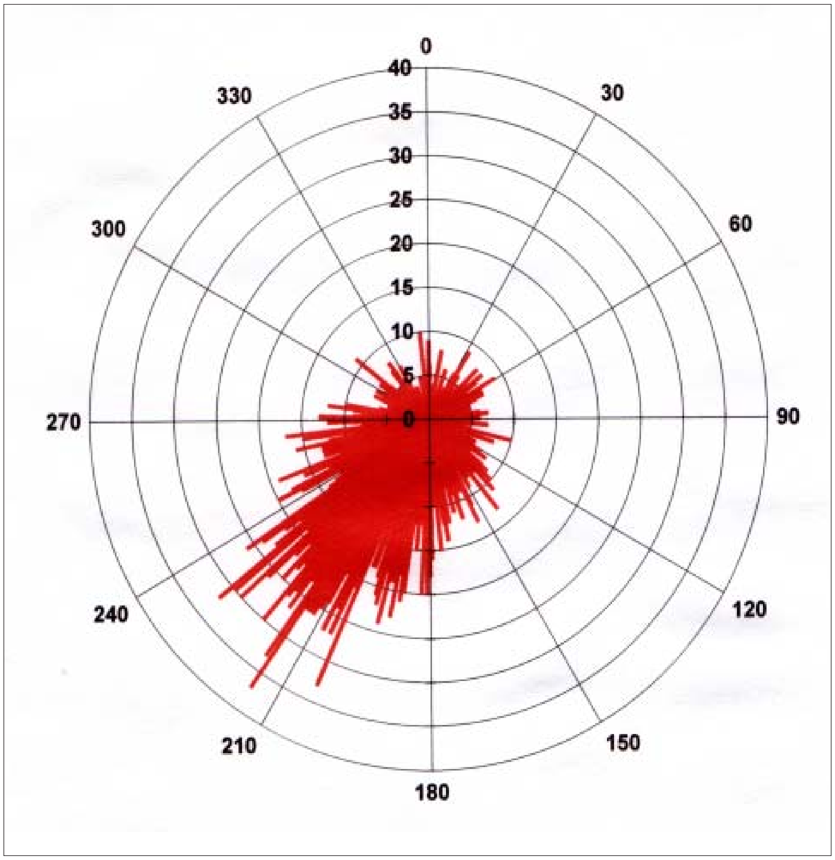


Figure 4.7. Wind rose at the 10-m level showing percentage of time for the major wind directions as recorded at the Berlin Heights, Ohio meteorological tower: 1973-1975 (from Ohio Edison Company 1977).



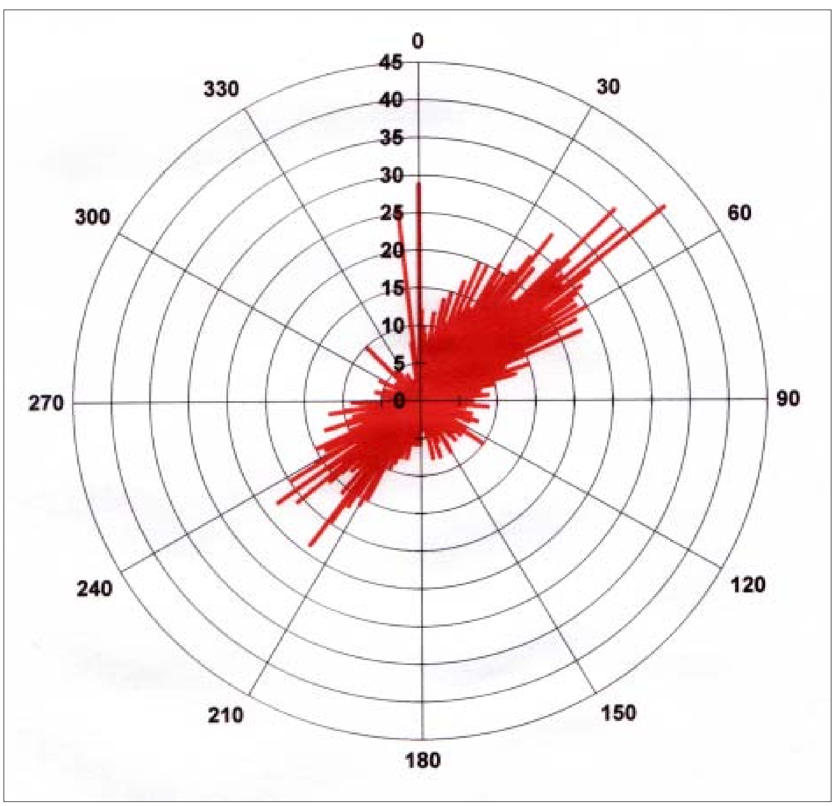


Figure 4.8. Monthly wind roses generated from measurements at Old Woman Creek Center showing dominant southwest wind patterns in the fall and the influence of northeast storms in the spring.

TABLE 4.9. RELATIONSHIP OF OVER LAND TO OVER LAKE PRECIPITATION AND WINDS FOR WESTERN LAKE ERIE

	Ratios			Ratios	
	Precipitation	Winds		Precipitation	Winds
JAN	1:1.02	1:1.96	JUL	1:0.88	1:1.16
FEB	1:0.88	1:1.94	AUG	1:1.00	1:1.39
MAR	1:0.97	1:1.88	SEP	1:1.95	1:1.78
APR	1:1.06	1:1.81	OCT	1:0.90	1:1.99
MAY	1:1.04	1:1.71	NOV	1:0.96	1:2.09
JUN	1:0.87	1:1.31	DEC	1:0.95	1:1.98
			MEAN	1:0.95	1:1.66

Data Sources: Richards and Phillips (1970), Bolsenga and Herdendorf (1993)

SOLAR RADIATION

The Old Woman Creek watershed experiences a maximum of about 15 hours of daylight in the summer and a minium of 9 hours in the winter (Herdendorf 1987). Because of the cloud-producing effect of the lake, December and January ordinarily have less than 40% of possible sunshine, while June and July average more than 70%. Table 4.10 gives the mean daily solar radiation received at the surface of Lake Erie. Photosynthetically active radiation (PAR) at the Reserve is measured in joules per second per square meter and in micromoles per second per square meter (400 to 700 nm waveband) with a Li-Cor quantum sensor (model LI-190SZ) . Figure 4.9 depicts the average daily PAR values recorded at the Reserve for 1997. The various units that are used to express solar radiation and conversion factors are presented in Table 4.11.

TABLE 4.10. SOLAR RADIATION RECEIVED AT THE SURFACE OF WESTERN LAKE ERIE

	Sunlight (hours)	Solar Radiation (kcal day^{-1} m^{-2})	Radiant Energy Flux (joules s^{-1} m^{-2})	Irradiance (PAR) (μE s^{-1} m^{-2})	Irradiance (PAR) (photons)
JAN	9.4	1,100	136	567	3.5×10^{22}
FEB	10.5	1,900	211	894	5.4×10^{22}
MAR	11.9	2,900	284	1,202	7.2×10^{22}
APR	13.2	3,900	342	1,448	8.8×10^{22}
MAY	14.6	4,500	359	1,519	9.1×10^{22}
JUN	15.2	5,500	420	1,778	10.7×10^{22}
JUL	14.9	5,500	429	1,813	10.9×10^{22}
AUG	13.9	4,700	394	1,667	10.0×10^{22}
SEP	12.6	3,700	342	1,448	8.7×10^{22}
OCT	11.2	2,400	250	1,057	6.4×10^{22}
NOV	9.8	1,300	154	652	3.9×10^{22}
DEC	9.1	900	115	486	2.9×10^{22}

Data Source: U.S. Fish and Wildlife Service (Herdendorf 1987)

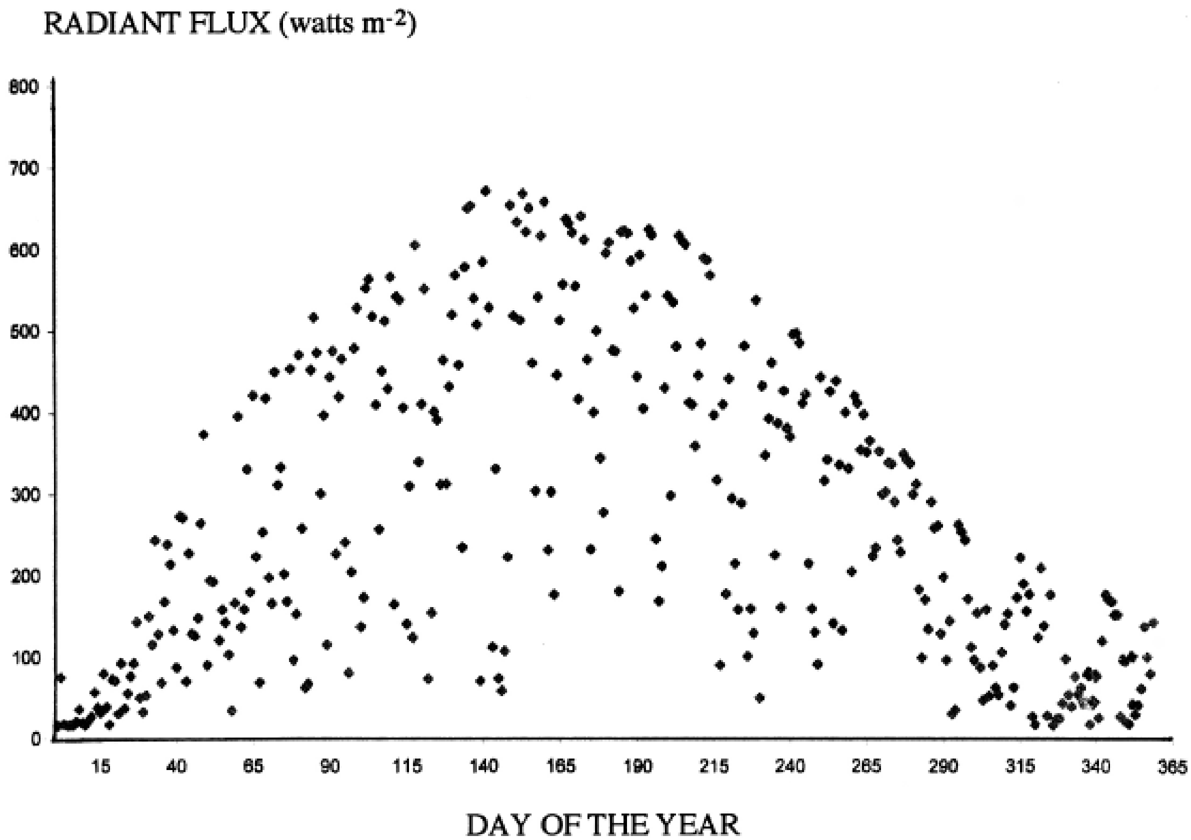


Figure 4.9. Mean daily solar radiation (PAR) measurements for 1997 at Old Woman Creek National Estuarine Research Reserve.

TABLE 4.11. CONVERSION FACTORS FOR SOLAR RADIATION MEASUREMENTS

1 foot candle = 1 lumen ft^{-2}

1 lux = 1 lumen m^{-2}

1 langley = 1 calorie m^{-2}

1 calorie = 4.19 joules

1 joule s^{-1} m^{-2} = 1 watt m^{-2}

1 joule = 4.3 µeinsteins (µE) [estimated mean value for visible light]

1 µmol s^{-1} m^{-2} = 1 µE s^{-1} m^{-2}

1000 µmol s^{-1} m^{-2} = 6.39 microamps

1 µE s^{-1} m^{-2} = 6.02×10^{17} photons (quanta) = 5.12×10^{-1} lux (estimate)

Full sun at zenith has an approximate PAR value of 2000 µmol s^{-1} m^{-2} or 2000 µE s^{-1} m^{-2}

Data Source: Herdendorf (1987)

ICE COVER

The shallow mean depth of Lake Erie and its associated small thermal reserve gives this Great Lake the most rapid response to changing atmospheric conditions. Ice cover extends over 90% of Lake Erie's surface most winters (Assel et al. 1983). Only during the last half of December and in April are there any persistent areas of open water. Ice cover usually develops in the western end of the lake in the last half of December. Likewise, Old Woman Creek estuary ices over at the same time or slightly earlier (Figure 4.10). During early March western Lake Erie usually has 40% to 60% coverage with ice and by the end of the month the estuary and adjacent Lake Erie are open water. Table 4.12 gives the normal and extremes of ice cover off the mouth of Old Woman Creek estuary for the period 1960 to 1979. Rafting of ice can cause considerable concentration and grounding of ice flows along the shoreline, which at times can form windrow several meters high.

TABLE 4.12. ICE COVER ON LAKE ERIE OFF OLD WOMAN CREEK ESTUARY (1960–1979)

Period	Maximum	Minimum	Normal Cover
December 16-31	0-10%	0-10%	0-10%
January 1-15	100%	0-10%	40-60%
January 16-31	100%	0-10%	0-10%
February 1-14	100%	0-10%	70-90%
February 15-28	100%	0-10%	70-90%
March 1-15	100%	0-10%	0-10%
March 16-31	40-60%	0-10%	0-10%
April 1-15	100%	0-10%	0-10%
April 16-30	0-10%	0-10%	0-10%

NOTE: (1) 0 to 10% (open water)—large area of freely navigable water in which some ice flows could be present; (2) 10 to 30% (very open pack)—pack ice in which water predominates over ice; (3) 40 to 60% (open pack)—pack ice with many leads and polynyas, where flows are generally not in contact with each other; (4) 70 to 90% (close pack)—pack ice in which the ice flows are mostly in contact; (5) 100% (consolidated pack)—pack ice in which the ice flows are frozen together

Data Source: NOAA, Great Lakes Environmental Research Laboratory (Assel et al. 1983)

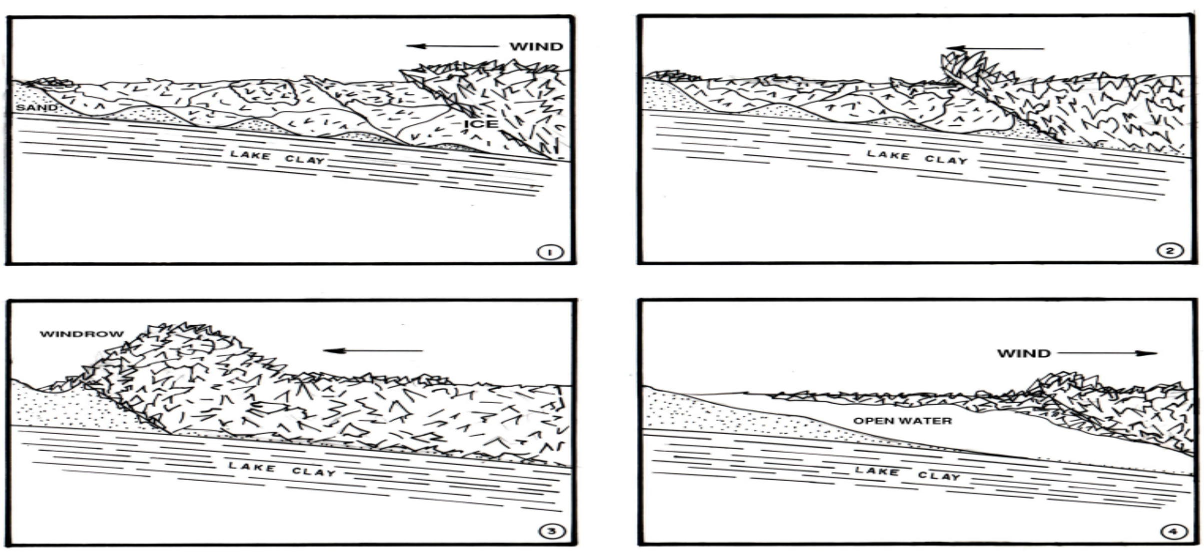


Figure 4.10. Sequence of events as ice moves onshore and offshore modifying the lake bottom at Old Woman Creek barrier bar (modified from Liebenthal and Herdendorf 1966).

How Weather Affects the Estuary

Storm events have a major impact on the water quality and quantity in Old Woman Creek estuary as well as the biota dwelling here. When heavy rain storms occur, turbid and chemically-laden waters flood the estuary from the watershed, frequently breaching the barrier beach and opening a connection with Lake Erie. Under these conditions the estuary is poorly able to assimilate watershed contaminants. When the barrier is open, lake biota can enter and reside in the estuary. However during periods with no severe storms, the barrier beach remains closed giving the estuary time to transform contaminants or settle them to the bottom. Estuary waters are further cleansed as they slowly percolate through the sands of the barrier beach. When the barrier is closed the biota in the estuary is distinctly different from that of Lake Erie. For example, during open periods the phytoplankton is dominated by small diatoms and flagellates, whereas when the barrier beach is closed, larger green algae, such as *Scenedesmus* spp., and some blue greens are dominant (Klarer 1999). This phenomenon is further discussed in the Ecology chapter of this profile.

Lee et al. (1995) modeled the impacts of climate change on water levels in western Lake Erie resulting from a doubling of atmospheric carbon dioxide. With a changed climate Detroit River flow would decrease by 36% which would result in a drop in the long-term average annual water level of 1.5 m for Lake Erie (from an elevation of 174.3 to 172.8 m). A decline in water level of this magnitude would result in very significant decreases in water volume and surface area. Water volume for Lake Erie would fall 20%, and surface area decrease would result in the losses of wetlands, freshwater estuaries, and embayments. Estuaries, such as Old Woman Creek estuary, would only be inundated during lake storm events or when lake levels would rise above the long-term climate change levels. Some migration of coastal wetlands may be expected, but most of Lake Erie's coastal wetlands would not be able to migrate lakeward due to man-made dikes or natural barrier beaches.

Storm surges and associated seiche activity can significantly raise the water level along the lakeshore to a point where lake water intrudes into the estuary. This is particularly prevalent during northeast storm events. The degree of this influence can be seen by measurements of water levels and conductivity at both the estuary mouth and at the upper end of the estuary. Because Old Woman Creek water is considerably more mineralized than lake water, conductivity measurements can give signatures to these two distinct water masses.

Measurements of the water level at the mouth on July 5, 1995 revealed a bimodal pattern with a period of about 13 hours between the high water periods. Conductivity, correspondingly, showed marked decline when water levels increased (Figure 4.11). The rise in water level was the result of an influx of lake water caused by a wind tide. This influx of water resulted in a decrease in conductivity (lake water has a lower conductivity than creek or estuary water). Seiche activities on Lake Erie have a period of 12 to 14 hours (Herdendorf and Krieger 1989). A similar pattern of water level change was recorded at the upper end of the estuary (Figure 4.12).

Despite the change in water level, there was no corresponding change in conductivity at upper site. This suggests that the change in water level originated from the lake and not from a watershed storm (which would have caused a drop in conductivity at this site). These measurements demonstrate that the intrusion of lake water was largely confined to the lower reaches of the estuary. However, the intrusion pushed resident estuary water upstream which resulted in a rise in water level at the upper end of the estuary, but no marked change in conductivity.

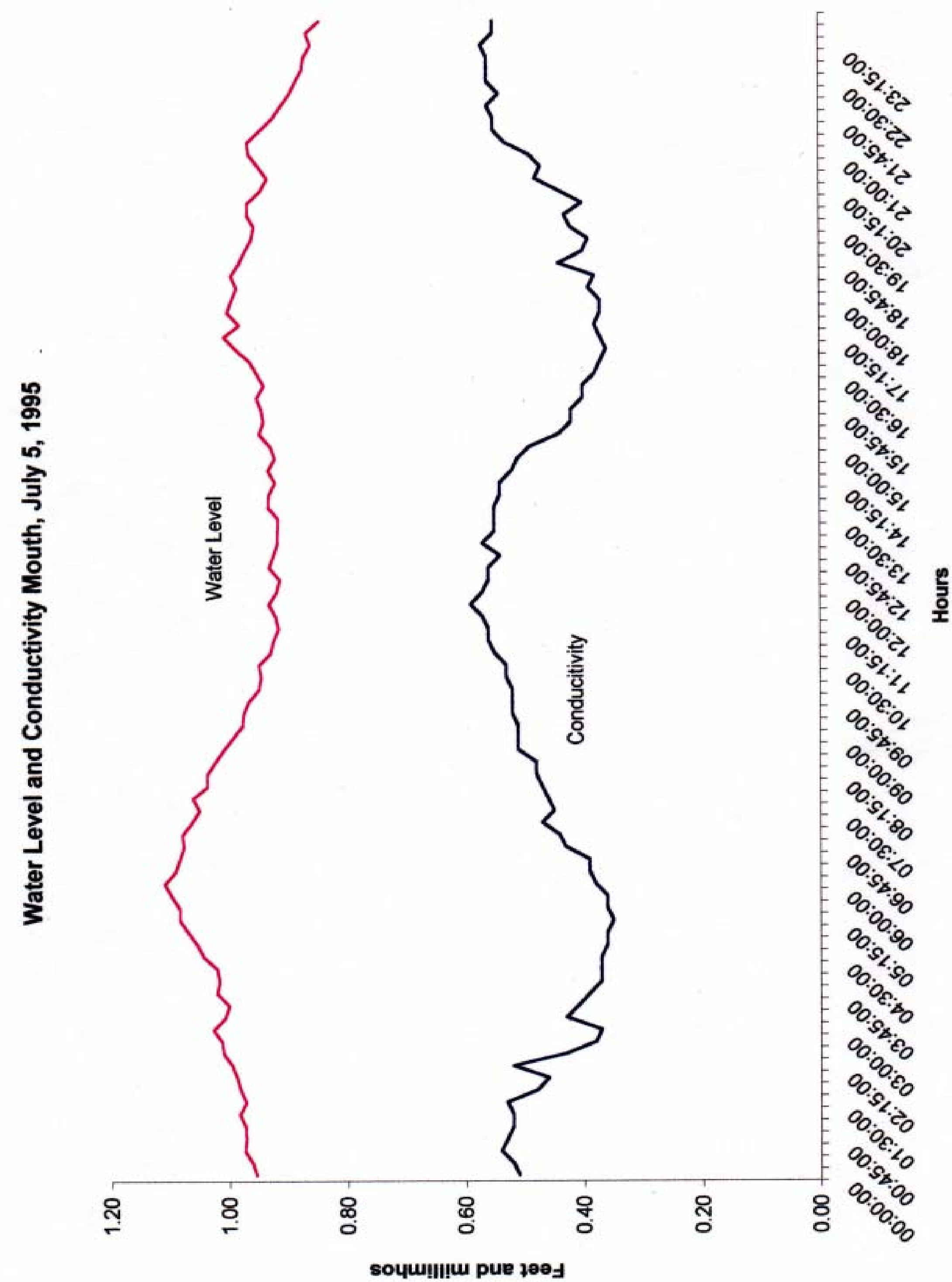


Figure 4.11. Measurements of water level (feet) and conductivity (millimhos) at estuary mouth on July 5, 1995.

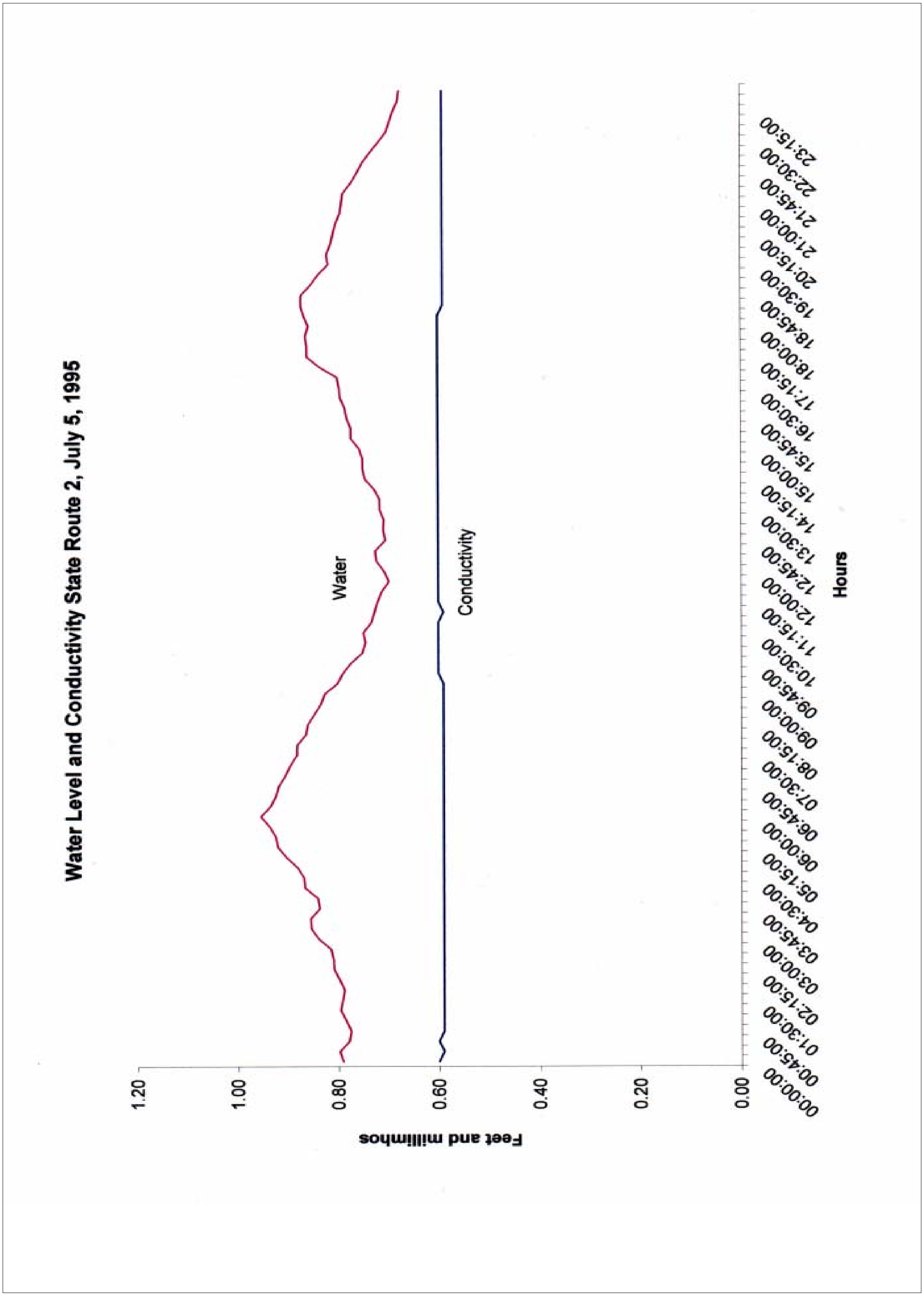


Figure 4.12. Measurements of water level (feet) and conductivity (millimhos) at upper end of estuary on July 5, 1995.

Breach in the barrier bar at the mouth of Old Woman Creek estaury following a storm (Charles E. Herdendorf).

Chapter 5. Hydrology

Lake Hydrology

The lower reaches of Old Woman Creek and the estuary are turbid throughout most of the year, owing to the silty nature of the soil and sediment resuspension by wind and lake action. Because of higher-than-average water levels in Lake Erie since the mid-1970s, former marshlands occupying this part of the watershed are now inundated. This condition has resulted in the flooding of approximately 60 hectares (150 acres), extending lake level some 2.1 km (1.3 mi) upstream. Historically, Lake Erie has exhibited extended periods of high and low water levels, which have caused the estuary to alternately be flooded and then to be dewatered. Commensurate with the lowering of water levels in Lake Erie, a trend that began in 1999, much of the once inundated Old Woman Creek estuary can be expected to again develop an extensive emergent vegetation marsh.

Lake-Flooding Potential

Floods within Old Woman Creek estuary can take place from two sources: (1) Lake Erie water entering via the estuary mouth and (2) watershed discharge entering via the main stem of Old Woman Creek and several smaller tributaries. In 1977 the U.S. Army Corps of Engineers (USACE), in conjunction with the Federal Insurance Administration, developed a procedure for establishing flooding potentials for the open coast of Lake Erie using the 1% value from a frequency curve of the maximum instantaneous high level each year. This level is comparable to the storm water level which results from a wind setup superimposed on the undisturbed water level of the lake, but does not include wave runup caused by waves rushing up the beach or a shore structure. Water level records from 1899 to 1974 were used to calculate the flooding potential for 24 reaches of the Lake Erie coast. The coast between Huron and Vermilion, Ohio, including the mouth of Old Woman Creek lies within reach "U." Open-coast flood levels were derived for 10-, 50-, 100-, and 500-year return periods; which represent the highest water levels along the coast that on the average will have a 10%, 2%, 1%, and 0.2%, respectively, chance of being equaled or exceeded in any given year. The predicted elevations for this reach are presented in Table 5.1.

Waves

The largest wind-generated waves on Lake Erie are those produced by large-area (synoptic-scale) circulation features such as extratropical and tropical cyclones (Figure 5.1). Smaller-scale wind phenomena (e.g. individual thunderstorms or squall lines) do not maintain winds over sufficient fetch to generate waves of comparable height. Resio and Vincent (1976) developed a wave hindcast model which predicts significant wave heights for return periods ranging from 5 to 100 years, for 24 grid points off the Lake Erie coast. Grid point "6" lies about 15 km off the barrier beach at Old Woman Creek. Seasonal extreme wave heights for this grid are presented in Table 5.2.

Wind Tides and Seiches

Wind tide or storm surge is a rapid rise in lake level resulting from the forced movement of surface water under the stress of wind. Once the wind has abated, the free oscillation (or sloshing) of the lake's surface is known as a seiche. Wind tide and seiche activity in the vicinity of Old Woman Creek can raise and lower the water level as much as 1 to 2 m (3 to 7 ft) or more in a single storm, but typical daily fluctuations are in the range of 0.1 to 0.2 m (0.3 to 0.7 ft). Seiches are an important factor in producing short-period water level oscillations in Lake Erie and in Old Woman Creek estuary. Owing to the orientation of the lake (longitudinal axis which nearly corresponds to the direction of the prevailing winds), the most common seiche is longitudinal and has a period of approximately 14 hours. Because of the estuary's position on the central basin of Lake Erie, the magnitude of the fluctuations are less pronounced than at the east and west ends of the lake.

Oscillation in lake level may also be set up by elevated atmospheric pressure bearing down upon a particular region of the lake or by a low pressure cell passing over the lake. Once the high or low pressure cell has passed, water either surges back or streams away in the process of reestablishing equilibrium, and exhibits the oscillatory movement of a seiche. A particularly intense cyclonic storm passed over Lake Erie in January 1978, when the lake was significantly ice covered. The low pressure cell crossed the lake

Figure 5.1. Waves from an April 1998 northeast storm batter the Lake Erie shoreline to the west of the Research Reserve (Charles E. Herdendorf).

from south to north near Lorain, Ohio, about 50 km (30 mi) east of the Reserve, inducing a noticeable water level rise (0.2 m or 0.7 ft) of a type that is rare for Lake Erie and usually only seen along the ocean coasts in response to hurricanes (Dingman 1980). The ensuing storm surge produced a 3-m (10-ft) difference in lake level between Old Woman Creek and Buffalo, New York, at the eastern end of the lake. Buffalo was flooded while Lorain reported a severe shortage of water at their treatment plant intake.

BEACH EROSION AND SHORELINE RECESSION

The barrier beach at the mouth of Old Woman Creek has experienced considerable recession in the past several decades. In 1956, the shore of the barrier beach was 220 m north of the U.S. Route 6 bridge (Herdendorf 1963a). By 1990 this distance had been reduced to 137 m. Thus, the center portion of the beach had migrated shoreward a distance of 83 m in the 34-year interval, a recession rate of 2.4 m/yr. During the same period, the length of the barrier beach was reduced from 520 m to 418 m. Hartley (1964) demonstrated that major shore structures, such as harbor jetties at Huron and Vermilion, had trapped large quantities of sand at the expense of the intervening shoreline. Serious beach erosion is evident along the 16.8 km reach between these two harbors, which includes the Old Woman Creek barrier beach. The main agents of beach erosion are wind, lake levels, waves, currents, and ice (U.S. Army Corps of Engineers 1946, 1953; Carter and Guy 1980).

LAKE WATER QUALITY

Lake Erie has undergone major changes in its chemistry and biology over the last 25 years. Nutrient inputs into the lake, particularly from point sources, have diminished (Fuller et al. 1995) and invasions by exotic species, particularly the zebra mussel *Dreissina polymorpha* (Hebert et al. 1991), have changed the ecology of Lake Erie very dramatically. Unfortunately, detailed chemical monitoring in the nearshore zone of Lake Erie over the ice-free periods has not been routinely undertaken for many parameters.

TABLE 5.1. FLOODING POTENTIAL OF THE LAKE ERIE COAST AT OLD WOMAN CREEK MOUTH

Return Period	+ MLS 1929[1]		+ IGLD 1955[2]		+ IGLD 1985[3]		+ LWD[4]		+ Mean[5]	
	meters	feet	meters	feet	meters	feet	meters	feet	meters	feet
10-year	175.5	575.9	175.0	574.3	175.2	574.9	1.7	5.7	1.1	3.6
50-year	175.8	576.8	175.3	575.2	175.5	575.8	2.0	6.6	1.4	4.5
100-year	175.9	577.0	175.4	575.4	175.6	576.0	2.1	6.8	1.5	4.7
500-year	176.1	577.6	175.6	576.0	175.7	576.6	2.3	7.4	1.7	5.3

NOTES:
1. Mean Sea Level 1929 (New York City mean tide level)
2. International Great Lakes Datum 1955 (Father Point, Quebec mean water level)
3. International Great Lakes Datum 1985 (Rimouski, Quebec mean water level)
4. Low Water Datum (LWD) = NOAA/USACE Chart Depth:
   LWD referred to MLS 1929 = 173.8 m (570.2 feet)
   LWD referred to IGLD 1955 = 173.3 m (568.6 feet)
   LWD referred to IGLD 1985 = 173.5 m (569.2 feet)
5. Mean Water Level = 0.64 m (2.1 feet) above LWD
6. Ordinary High Water Mark (OHWM) = 1.28 m (4.2 feet) above LWD

Data Source: U.S. Army Corps of Engineers (1977)

TABLE 5.2. ESTIMATES OF EXTREME LAKE ERIE WAVES OFF OLD WOMAN CREEK, OHIO

Return Period	Northwest Storm		North Storm		Northeast Storm	
	Height (m)	Period (sec)	Height (m)	Period (sec)	Height (m)	Period (sec)
SPRING						
10-year	1.5±0.2	5.6	1.0±0.2	4.6	1.5±0.3	5.7
50-year	2.2±0.2	6.3	1.8±0.3	6.0	2.7±0.4	7.0
100-year	2.5±0.3	6.6	2.1±0.3	6.3	3.2±0.5	7.4
SUMMER						
10-year	1.5±0.2	5.6	1.3±0.3	5.3	1.5±0.5	5.7
50-year	1.9±0.4	6.0	1.7±0.4	5.9	2.3±0.9	6.6
100-year	2.1±0.4	6.2	1.9±0.5	6.1	2.7±1.0	7.0
FALL						
10-year	2.4±0.2	6.5	2.7±0.1	7.0	2.9±0.3	7.2
50-year	3.0±0.2	7.0	3.2±0.2	7.4	4.3±0.5	8.4
100-year	3.3±0.3	7.3	3.4±0.2	7.7	4.8±0.5	8.9
WINTER						
10-year	2.2±0.2	6.3	3.1±0.2	7.4	2.7±0.2	7.0
50-year	3.3±0.3	7.3	4.0±0.3	8.3	3.6±0.3	7.7
100-year	3.7±0.4	7.7	4.4±0.4	8.7	3.9±0.4	8.0

Data Source: U.S. Army Corps of Engineers (Resio and Vincent 1976)

HURON HARBOR WATER QUALITY STUDY

Between April and November 1976, the U.S. Environmental Protection Agency (Gedeon 1977) performed 16 water quality surveys in Lake Erie near the Huron Harbor, Ohio Dike Disposal Facility. A Total of 17 chemical and physical parameters were measured at six lake stations (two background and four near the dike) and one river station. The background stations serve as a useful set of baseline data for nearshore lake conditions in the vicinity of Old Woman Creek estuary, a few years prior to the establishment of the Research Reserve. Measurements were taken 0.5 m below the surface and 0.5 m above the bottom (Table 5.3). Water depths at the two background stations were in the range of 3.0 to 4.0 m. The following section outlines the seasonal water quality trends noted for spring through autumn 1976.

Turbidity and Suspended Solids

Strong northerly winds caused re-suspension of lake bottom sediments as evidenced by high turbidity values obtained in April which were fairly uniform throughout the water column. From May through November turbidity values were relatively low, rarely exceeding 10 JTU. Since there is a direct relationship between turbidity and suspended solids, the seasonal patterns of these two parameters were very similar.

Phosphorus

Ortho-phosphorus constituted about 35% of the total phosphorus present in the water and alone exceeded the Ohio Environmental Protection Agency (EPA) water quality standard for total phosphorus of 25 μgm/l during most of the period from April through July. Ortho-phosphorus represents the most biologically active form of phosphorus dissolved in the lake water. Total phosphorus exceeded the Ohio EPA standards for the entire study period, with the exception of November when the concentration dropped to about 20 μgm/l. Bottom waters exhibited the highest concentrations, most likely the result of releases from the sediments.

Nitrogen

Nitrate-nitrite concentrations were the highest in early April and declined steadily to near zero by mid-September. As the concentration of dissolved oxygen increased in October and November, concentrations of nitrate-nitrite also increased. Ammonia nitrogen was below 0.10 mg/l most of the time and averaged only 0.04 mg/l. However, during the period from April until late June, total inorganic nitrogen (sum of nitrate, nitrite, and ammonia concentrations) exceeded the Ohio EPA standards of 0.30 mg/l for Lake Erie. Total Kjeldahl nitrogen (organic nitrogen) concentrations approximately doubled between mid-April and early August (0.49 to 0.88 mg/l). The early August peak corresponded with the highest water temperature and the optimum period for blue-green algae growth. Following this peak, the concentration of organic nitrogen declined steadily into November.

Chemical Oxygen Demand

Following the high demand values (20-40 mg/l) caused by turbulent lake conditions in early April, the demand values dropped to 10-15 mg/l for most of the summer and autumn. The values for the later half of the year were at or near the maximum limit of 12 mg/l for Ohio EPA water quality standards for nearshore waters of Lake Erie.

Total Iron, Manganese, and Arsenic

During periods of high water turbidity, high total iron concentrations were also observed. Re-suspension of bottom sediments resulting from strong northerly winds appears to have been the major cause of the high values. The average total iron concentration was 873 μg/l. The Ohio EPA standard of 300 μg/l was exceeded a majority of the time, except in late summer when at times values decreased to <200 μg/l. Total manganese followed a similar seasonal pattern as iron, but only exceeded Ohio EPA standards of 50 μg/l in early April. Arsenic was detected at very low levels (<2 μg/l), well below the Ohio EPA standard of 5 μg/l for nearshore waters of central Lake Erie.

Oil and Grease

During April, low concentrations of oil and grease were found in surface and bottom water (1-2 mg/l), which were attributed to decomposing organic matter which was re-suspended by the turbulent lake conditions at the time. For the remainder of the year most values were <1 mg/l.

TABLE 5.3. LAKE ERIE NEARSHORE WATER PROPERTIES IN 1976

	Range	Mean
Turbidity (JTU)		
Surface	4-55	16
Bottom	4-85	19
Suspended Solids (mg/l)		
Surface	5-71	20
Bottom	5-197	29
Ortho-phosphorus (μg/l as P)		
Surface	<5-48	21
Bottom	<5-96	24
Total Phosphorus (μg/l as P)		
Surface	20-120	61
Bottom	<20-300	69
Nitrate + Nitrite (mg/l as N)		
Surface	<0.03-3.01	0.42
Bottom	<0.03-2.98	0.43
Ammonia (mg/l as N)		
Surface	<0.03-0.13	0.04
Bottom	<0.03-0.22	0.04
Total Kjeldahl Nitrogen (mg/l as N)		
Surface	0.26-1.00	0.55
Bottom	0.25-1.58	0.57
Chemical Oxygen Demand (mg/l)		
Surface	5-26	13
Bottom	6-41	14
Iron (μg/l as Fe)		
Surface	185-3,250	793
Bottom	193-5,000	952
Manganese (μg/l as Mn)		
Surface	7-46	20
Bottom	8-170	26
Arsenic (μg/l as As)		
Surface	<2	<2
Bottom	<2	<2
Oil and Grease (mg/l)		
Surface	<1-2	<1
Bottom	<1-1	<1
Temperature (°C)		
Surface	5.7-22.9	14.9
Bottom	5.7-22.8	14.6
Dissolved Oxygen (mg/l)		
Surface	3.2-11.8	7.5
Bottom	3.1-11.5	7.3
Eh (millivolts at 25°C)		
Surface	244-389	298
Bottom	244-424	308
pH (standard units)		
Surface	7.8-8.5	8.2
Bottom	7.8-8.5	8.1
Conductivity (μmhos at 25°C)		
Surface	246-333	280
Bottom	240-315	278
Currents (knots/hr)		
Surface	0.05-0.60	0.27
Bottom	0.08-0.75	0.31

Data Source: U.S. Environmental Protection Agency (Gedeon 1977)

Temperature

Following the typical annual trend, water temperature gradually increased from about 6°C in early April to nearly 23°C in late July and early August. In late summer to autumn, temperatures declined rapidly, reaching about 4°C in early November (Table 5.4).

Dissolved Oxygen

Both surface and bottom dissolved oxygen (DO) concentrations steadily decreased from approximately 10 mg/l in April to about 3 mg/l in mid-September. DO concentrations then rapidly increased to over 11 mg/l by early November as a result of decreasing water temperatures and increased turbulence brought about by more northerly winds (Table 5.4).

Oxidation-Reduction Potential (Eh)

The waters of Lake Erie contained sufficient oxygen to inhibit anaerobic activity. Consequently, Eh values indicated waters of relatively high oxidative potential (i.e. oxidizing bacterial species were more abundant than reducing species).

Hydrogen-ion Concentration (pH)

Lake Erie nearshore waters were slightly alkaline. The values had a narrow range; the most frequently occurring (mode) pH was 8.2.

Conductivity

Specific conductance, the dissolved-ion concentration or mineralization of the lake water as measured by electrical conductivity, was relatively uniform. The background stations averaged 279 μmhos (1 μmhos = 1 μSiemen) which equates to approximately 200 ppm of dissolved solids or a salinity of 0.2% (about 0.57% the salinity of mean sea water).

Currents

Nearshore currents were typically generated by sustained wind, most commonly from a southwesterly direction. The surface currents generally followed the direction of the wind but the bottom currents were more complex, at times opposed to the wind direction, presumably a compensating return flow for the water removed by the surface currents.

TABLE 5.4. TRENDS IN AVERAGE TEMPERATURE AND DISSOLVED OXYGEN OF LAKE ERIE NEARSHORE WATERS IN 1976

Date	Temperature (C°)	Dissolved Oxygen (mg/l)
Apr 5	5.9	9.0
Apr 8	7.6	10.0
Apr 12	7.0	10.2
Apr 15	9.6	10.9
May 17	13.8	9.6
Jun 7	17.8	6.8
Jun 14	21.4	5.6
Jun 21	20.6	7.2
Jul 21	22.4	6.0
Aug 4	22.8	4.0
Sep 8	19.7	7.4
Sep 16	19.8	3.3
Sep 23	16.6	5.0
Sep 30	15.8	4.8
Oct 19	10.8	6.4
Nov 9	4.4	11.6
Mean	14.8	7.4

Data Source: USEPA (Gedeon 1977)

WATER INTAKE STUDIES

Since the 1976 Huron study, no published water quality studies have been conducted in the nearshore zone near the Reserve. However, data from the Sandusky water treatment plant intake (Table 5.5) for the period 1997-2001 shows that locally many of these parameters have not changed significantly over this 25 year period. Chemical parameters measured both at Sandusky and in the nearshore zone of Lake Erie by the Old Woman Creek monitoring program had many similarities during the 1998-2000 period (see Estuary Water Quality section later in this chapter).

The Huron water treatment plant monitors parameters on a daily basis, including pH, alkalinity, and turbidity. Data for the period 2000-2001 is presented in Table 5.6. These data are quite different from those collected during 1998-2000 in the nearshore zone Old Woman Creek. The cause of the difference is unknown, but may be related to the proximity of the Old Woman Creek monitoring site to the lake shore (2 to 5 m from shore, 1 m depth) as compared with the Huron site (400 m offshore, 5 m depth) and the time of day samples were collected. Another factor may be Old Woman Creek discharge at the nearshore station.

TABLE 5.5. LAKE ERIE WATER QUALITY AT SANDUSKY, OHIO WATER INTAKE FOR 1997 TO 2001

Parameter	Range	Mean
Suspended Solids -mg/l	2.5-56	18.5
Total Phosphorus- µg/l P	21-100	39.9
Nitrate + Nitrite- mg/l N	0.12-1.54	0.576
Ammonia- mg/l N	0.025-0.140	0.057
Total Kjeldahl Nitrogen-mg/l	0.02-0.44	0.212
Chemical Oxygen Demand-mg/l	<10	<10
Iron- µg/l	155-1985	820
Manganese- µg/l	18-295	92
Arsenic- µg/l	<2-2.2	<2
pH- Standard Units	8.02-8.22	8.11
Conductivity- µmhos/ cm	259-323	283
Total Alkalinity- mg $CaCO_3$/l	77-92	84.7
Calcium- mg/l	29-38	33
Magnesium- mg/l	8-10	9.5
Chloride- mg/l	12-20.4	15.2
Sodium- mg/l	6-12	8.6
Sulfate-mg/l	18-41	28.1

Data Source: Ohio EPA (courtesy Doug Keller, City of Sandusky Water Treatment Plant)

TABLE 5.6. LAKE ERIE WATER QUALITY AT HURON, OHIO WATER INTAKE FOR 2000 AND 2001

Parameter	Range	Mean
pH- Standard Units	7.2-8.6	7.9
Total Alkalinity- mg $CaCO_3$/l	85-112	98
Turbidity- NTU	0.9-129	15.3

Data Source: City of Huron Water Treatment Plant (courtesy of Ron Marsnic)

ESTUARY HYDROLOGY

Like the oceans, the Great Lakes possess estuarine-like environments in the lower reaches of many tributary streams. Such estuaries are particularly prevalent along the south shore of Lake Erie where crustal rebound, following deglaciation, has resulted in the outlet (Niagara River) rising over 30 m in relation to this shore (Herdendorf 1990). As a result, the lower courses of the southern tributaries have been flooded by the encroaching lake, creating the drowned river mouths typical of estuarine systems.

Coastal wetlands, particularly freshwater estuaries, of the Great Lakes play an important role in mitigating adverse impacts to the lakes by pollutants entering the wetlands from the watersheds and the atmosphere. Here, various chemical, physical, and biological processes transform and trap pollutants, sediments, and nutrients, storing them temporarily or permanently in the wetland. In the absence of wetlands all of these materials would enter the lake directly. Understanding the hydrologic processes which govern the exchange of water between the estuary and lake is fundamental in determining water storage and the flux of materials through these systems.

The mouth of Old Woman Creek has been classified as an estuary because it possesses many features analogous to typical saltwater estuarine systems (Brant and Herdendorf 1972). It is a semi-enclosed body of water that for most of the time has a free connection with the lake. Water exchange in the estuary is primarily driven by wind tides and seiches in Lake Erie and by stream drainage from the catchment. Because of the highly mineralized water from the catchment, a chemical gradient exists between the waters of Lake Erie and Old Woman Creek. Physical features typical of estuaries include the narrow mouth, a barrier beach sheltering the estuary from the lake, perimeter mud flats, and freshwater marshes.

Old Woman Creek drains approximately 69 km^2 (27 mi^2) of primarily agricultural land. The estuary consists of the lower 2.1 km (1.3 mi) of the creek which flows into southwestern Lake Erie. Morphologically the estuary is divided into 3 parts: (1) the upper estuary, or south basin, is comprised of a narrow creek-like channel (which during high water levels spills out over adjacent swampy land) that terminates in a shallow lagoon where a railway causeway constricts drainage, (2) the central or main estuary is a shallow basin cut by a narrow drainage channel along its western margin that terminates where a highway causeway constricts drainage, and (3) a small, elongated lake lagoon that lies between the road causeway and the sandy barrier (Oberlin Beach) that separates the estuary from Lake Erie. For ease of designation, the basins are hereafter referred to as “South,” “Main,” and “Lake Lagoon,” respectively. Table 5.7 presents a comparison of surface area, water volume, and mean depth under several water level conditions for the three basins. The total estuary area (including the upper swamps is about 0.6 km^2 (60 hectares or 150 acres). Bottom sediments in the estuary are unconsolidated muds that are resuspended by wave action to give the estuary water its characteristic turbid appearance. The location and dimensions of the estuary mouth are constantly changing in response to variations in stream flow, currents generated by water level differences between the estuary and the lake, and wave action which modifies the barrier beach. Under certain conditions the beach barrier completely bars off the estuary and the system becomes lacustrine for extended periods. Table 5.8 presents a history of the open conditions of the estuary bar from 1983 to 2000.

HYDROGRAPHIC AND BATHYMETRIC SURVEY

Because only a generalized bathymetric map (Buchanan 1982) and no comprehensive description of the hydrology of Old Woman Creek estuary was available, a hydromorphometric study of the estuary was undertaken in 1990 (Herdendorf and Hume 1991). The objectives of the study were to: (1) map the bathymetry of the estuary, (2) determine the factors controlling temporal variations in the hydrologic characteristics and water storage capacity of the estuary, and (3) examine the role the estuary plays in the exchange of water between the watershed and Lake Erie. Depth soundings were made along 43 transects at nearly 1,000 locations (Figure 5.2). Water levels were monitored during the surveys at a recorder established by the U.S. Geological Survey in the estuary at the lakeshore. Additional information was gained from vertical aerial photographs that had been taken at various water level stages in 1937, 1949, 1950, 1956,

TABLE 5.7. BASINS OF OLD WOMAN CREEK ESTUARY

Basin	Water Level (m + LWD)	Area (m^2)	Volume (m^3)	Mean Depth (m)
South	2.0	194,565	161,404	0.83
	1.0	74,333	28,892	0.39
	0.0	11,800	2,430	0.21
Main	2.0	425,000	578,292	1.36
	1.0	424,375	153,355	0.36
	0.0	3,463	1,672	0.48
	-1.0	1,115	306	0.27
Lake Lagoon	2.0	30,735	36,526	1.19
	1.0	20,752	10,766	0.52
	0.0	2,532	227	0.09

NOTE: Low Water Datum (LWD) = 173.5 m or 569.2 ft (IGLD, 1985) elevation

TABLE 5.8. RECORD OF OPEN CONDITIONS AT THE MOUTH OF OLD WOMAN CREEK ESTUARY

Days Open

Month	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	MEAN(%)
January	31	31	31	31	31	29	30	31	31	0	31	31	31	31	31	31	14	31	28.2 (91.0)
February	28	29	28	28	28	29	28	28	28	13	28	28	28	29	28	28	19	29	26.9 (95.1)
March	25	31	25	31	31	26	31	31	31	26	31	31	31	31	31	31	31	31	29.8 (96.1)
April	25	30	30	22	26	18	30	24	30	23	30	30	30	30	30	30	30	30	27.7 (92.3)
May	17	31	31	31	5	6	31	29	17	5	31	14	31	31	31	25	12	31	22.7 (73.2)
June	15	29	0	19	29	0	29	0	9	5	23	3	19	30	30	17	0	30	15.9 (53.0)
July	21	9	0	0	31	0	0	4	0	17	8	3	31	13	6	31	15	26	11.9 (38.4)
August	0	0	0	0	12	0	0	23	0	30	0	6	22	0	9	14	0	21	7.6 (24.5)
September	0	0	0	1	0	0	0	21	0	26	0	0	0	18	21	12	0	0	5.5 (18.3)
October	6	0	0	17	0	0	3	25	0	0	0	0	27	26	11	0	0	0	6.4 (20.6)
November	24	0	25	4	13	0	30	16	0	28	3	0	30	11	0	0	23	0	11.5 (38.3)
December	31	28	29	31	29	1	31	31	0	31	26	5	31	31	21	0	25	19	22.2 (71.6)
TOTAL	223	218	199	215	235	109	243	263	146	204	211	151	311	281	249	219	169	248	216.6 (59.3)
% YEAR	61.1	59.7	54.5	58.9	64.4	29.9	66.6	72.1	40.0	55.9	57.8	41.4	85.2	77.0	68.2	60.0	46.3	67.9	59.3

Figure 5.2. Hydrographic survey of a tributary stream within the Research Reserve (Charles E. Herdendorf).

1964, 1968, 1973, 1978, 1979, 1980, 1984, 1985, 1987, and 1989. Morphometric dimensions of the estuary were determined using the methods given in Welsh (1948), Hutchinson (1957), Reid and Wood (1976), Håkanson (1981), Cole (1983), and Wetzel (1983).

The resulting bathymetric map (Figure 5.3) has a contour interval 0.2 m. Each contour line was traced with an electronic planimeter to determine the bounded area, which allowed calculation of the volume of water stored within the estuary for water levels ranging from +2.0 m to -2.0 m LWD. The tabular area and volume calculations are plotted on hypsographic curves (Figures 5.4 and 5.5). Morphometric dimensions are presented in Table 5.9 and definitions and formulas for morphometric parameters are given in Table 5.10.

Examination of the bathymetric map reveals that Old Woman Creek estuary is, in general, a broad shallow water body. When the water level in the estuary is standing at the mean level of Lake Erie (174.1 m IGLD, 1985 or +0.6 m LWD) the average depth of the estuary is only about 0.2 m. During the survey period (October and November 1990) the mean depth of the estuary was nearly 0.4 m.

The south basin, at the upper end of the estuary, is characterized by a relatively deep, stream-like channel flanked by material levees along most of its course (Figures 2.13 and 6.14). A number of small lagoons are found along its left bank (looking downstream) and an extensive lagoon-swamp forest is found between the right levee and an escarpment along the east side of the estuary. The top of the channel levees lies at +1.8 to +2.0 m LWD, while the floor of the swamp forest is about +1.4 to +1.6 m LWD.

The main basin is more lake-like in appearance with a sizable island (Star Island) located near its center (Figures 2.10 to 2.12). The levees continue only at the southern end of this basin. The main basin is surrounded by relatively steep escarpments on all sides, including the island. Into the escarpment, on both the east and west banks, a number of deeply entrenched but shallow coves have been cut by intermittent tributaries. The main channel of this basin follows a course down the eastern side of the estuary. It is only a few tenths of a meter deeper than the generally flat bottom of the remainder of the basin. A minor channel was also detected on the back (western) side of Star Island. Major portions of this basin have a floor

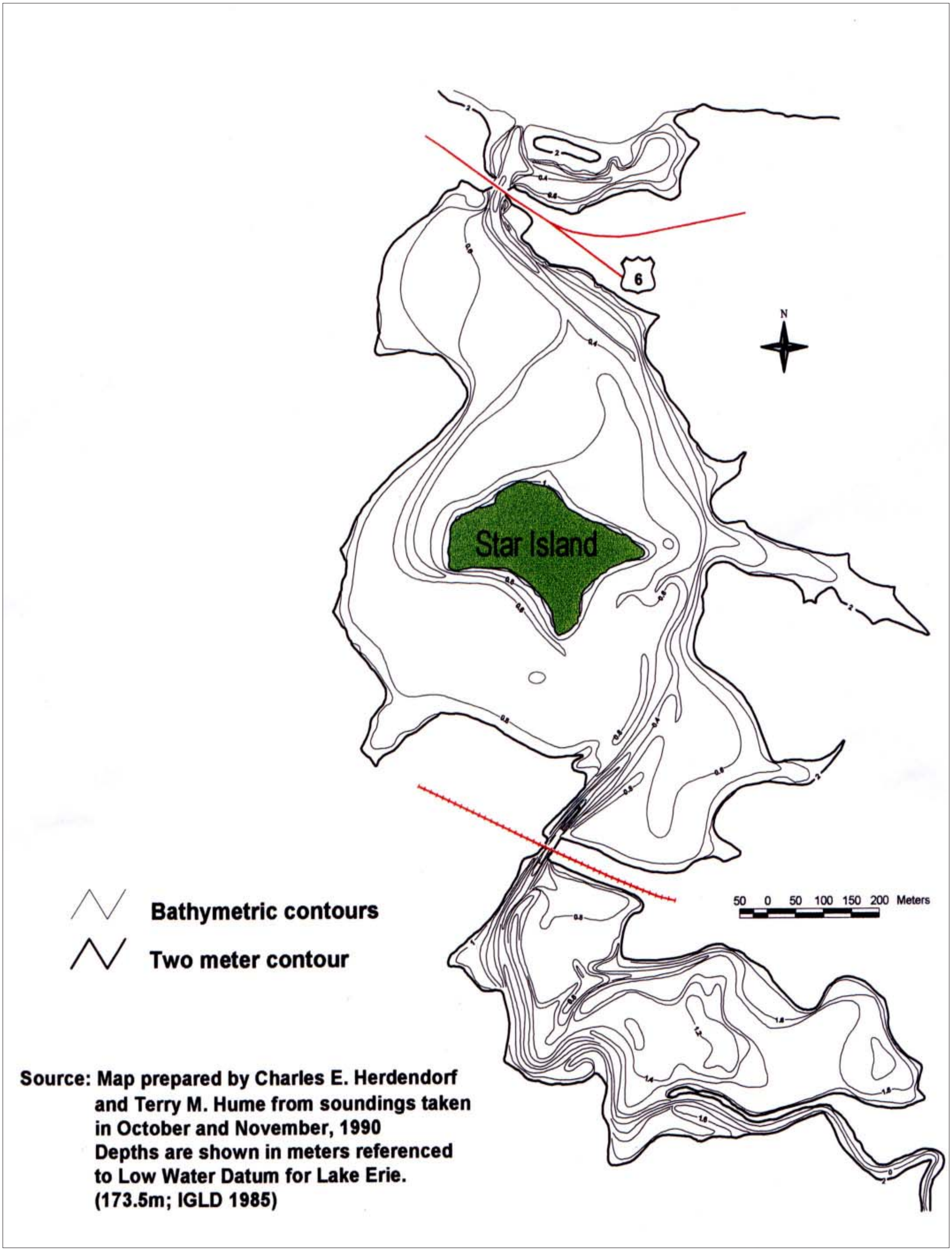


Figure 5.3. Bathymetric map of Old Woman Creek estuary (from Herdendorf and Hume 1991).

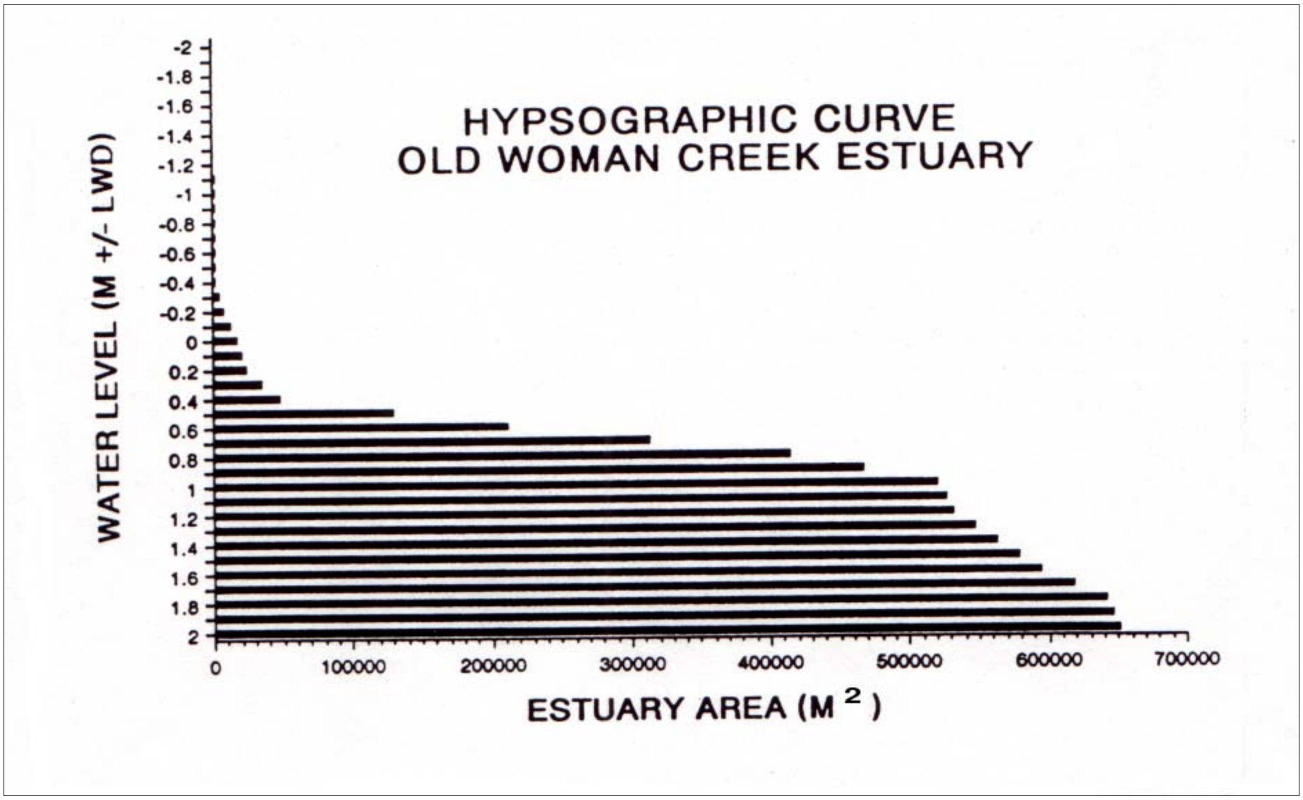


Figure 5.4. Hypsographic curve for Old Woman Creek estuary—area versus depth.

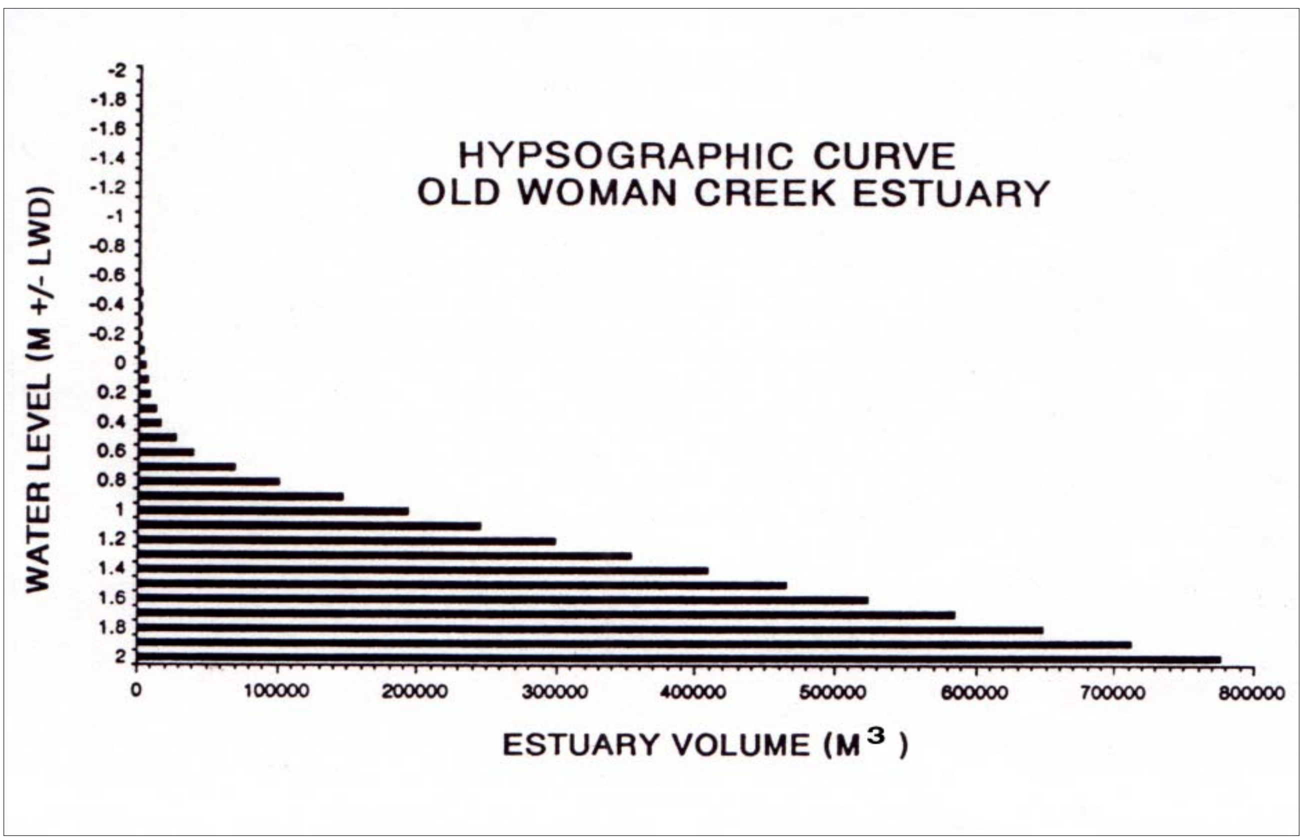


Figure 5.5. Hypsographic curve for Old Woman Creek estuary—volume versus depth.

TABLE 5.9. MORPHOMETRY OF OLD WOMAN CREEK ESTUARY

Parameter	Dimension[1]
MAXIMUM DEPTH (z_m)	2.68 m
South Basin	1.67 m
Main Basin	2.68 m
Lake Lagoon	2.46 m
MEAN DEPTH ($\bar{z}$)	0.37 m
RELATIVE DEPTH (z_r)	0.33%
MAXIMUM LENGTH (l)	2,000 m
MAXIMUM EFFECTIVE LENGTH (l_e)	1,125 m
MAXIMUM BREADTH (b)	670 m
MEAN BREADTH ($\bar{b}$)	260 m
CLOSURE INDEX (CI)	0.02
AREA (A)	519,460 m^2
VOLUME (V)	193,013 m^3
SHORE LENGTH (L)	9,616 m
INSULOSITY (I_n)	7.64% (Star Island)
SHORELINE DEVELOPMENT (D_l)	3.75
VOLUME DEVELOPMENT (D_v)	0.41
ORIENTATION OF MAIN AXIS	335° (N25°W)

SLOPE OF BASIN BETWEEN CONTOURS (S)

1.8 to 2.0 m	8.54%
1.6 to 1.8 m	1.89%
1.4 to 1.6 m	3.33%
1.2 to 1.4 m	2.86%
1.0 to 1.2 m	11.30%
0.8 to 1.0 m	1.79%
0.6 to 0.8 m	0.79%
0.4 to 0.6 m	0.92%
0.2 to 0.4 m	4.95%
0.0 to 0.2 m	12.14%
-0.2 to 0.0 m	5.98%
-0.4 to -0.2 m	8.75%

MEAN SLOPE (s) 1.85%

LENGTH OF CONTOUR LINES (L_z)

2.0 m	9,923 m	-0.2 m	2,892 m
1.8	10,162 m	-0.4	1,918 m
1.6	11,451 m	-0.6	505 m
1.4	10,972 m	-0.8	381 m
1.2	10,090 m	-1.0	235 m
1.0	9,616 m	-1.2	185 m
0.8	9,250 m	-1.4	133 m
0.6	8,298 m	-1.6	30 m
0.4	7,124 m		
0.2	4,258 m		
0.0	3,402 m		

NOTE: 1. Measurements based on estuary water level of +1.0 m LWD (= 174.49 m or 572.48 ft IGLD, 1985)

TABLE 5.10. DEFINITIONS OF HYDROMORPHOMETRIC PARAMETERS

MAXIMUM DEPTH (z_m)

The deepest sounding in m.

MEAN DEPTH ($\bar{z}$)

The relationship between the volume and surface area of a body of water:

$$\bar{z} = \frac{V}{A}$$

$\bar{z}$ = mean depth in m

V = volume in m^3

A = surface area in m^2.

For streams mean depth is defined as:

$$\bar{z} = \frac{a}{w}$$

where, $\bar{z}$ = mean depth in m

a = cross-sectional area of stream channel in m^2

w = stream width in m.

RELATIVE DEPTH (z_r)

The maximum depth of a lake or estuary expressed as a percentage of the mean diameter:

$$z_r = \frac{50 z_m \sqrt{\pi}}{\sqrt{A}}$$

where, z_r = relative depth in %

z_m = maximum depth in m

A = surface area in m^2

π = 3.14.

MAXIMUM LENGTH (l)

The length of line connecting the two most remote extremities of a lake (curved for oxbow lakes).

MAXIMUM EFFECTIVE LENGTH (l_e)

The straight line connecting remote extremities along which wind and wave action can occur without land interruption.

MAXIMUM BREADTH (b)

The maximum distance on a lake surface at a right angle to line of maximum length between shores.

MEAN BREADTH ($\bar{b}$)

The mean breadth or width of a body of water is defined by the equation:

$$\bar{b} = \frac{A}{1}$$

where, $\bar{b}$ = mean breadth in km

A = surface area in km^2

1 = length in km (distance between the farthest points on the shore of a lake or other body of water).

AREA (A)

The surface area, as measured with a planimeter or other means.

ORIENTATION OF MAIN AXIS

The compass directions of line of maximum length in degrees (°).

TABLE 5.10. DEFINITIONS OF PARAMETERS (cont'd)

CLOSURE INDEX (CI)

A dimensionless index of the comparative closure of an embayment, which relates the inlet opening of a bay to the diameter of a semi-circle that has an area equal to that of the embayment:

$$CI = \frac{D}{\sqrt{\frac{2A}{\pi}} \cdot 2}$$

where,
- D = embayment opening in km
- A = area of embayment in km^2
- CI = closure index
- π = 3.14.

Therefore, a perfectly semi-circular bay has an inlet opening exactly equal to the diameter of the semi-circle formed by the area, yielding a closure index of 1.0. Embayments with an index >1.0 are more broadly open and those <1.0 have more constricted inlets.

VOLUME (V)

The total volume of a lake or estuary can be determined by deriving the amount of water contained in each of the strata bounded by depth contours. The volume of a stratum can be calculated by the formula:

$$V_s = \frac{1}{3} (A_1 + A_2 + \sqrt{A_1 \cdot A_2})\, z$$

where,
- V_s = volume of a stratum in m^3
- A_1 = area of the upper surface of a contour stratum in m^2
- A_2 = area of the lower surface of a contour stratum in m^2
- z = depth or contour interval of the stratum in m.

The sum of the volumes of all the strata yields the total volume of the lake.

SHORE LENGTH (L)

The perimeter length of the shoreline in m.

INSULOSITY (I_n)

The percentage of the total area of a lake that is occupied by islands, islets and exposed rocks:

$$I_n = \frac{A_i \cdot 100}{A}$$

where,
- I_n = insulosity in %
- A_i = area of islands in m^2
- A = surface area in m^2.

SHORELINE DEVELOPMENT (D_l)

A quantitative expression derived from the shape of a lake, defined as the ratio of the shoreline length to the length of the circumference of a circle of the same area as the lake:

$$D_l = \frac{L}{2\sqrt{\pi A}}$$

where,
- D_l = shoreline development, a dimensionless index number
- L = length of the shoreline in km
- A = area of lake surface in km^2
- π = 3.14.

Since the ratio is related to a circle, a perfectly round basin would have an index of 1.0. Increasing irregularity of shoreline in the form of embayments and projections results in an increase in the index number.

TABLE 5.10. DEFINITIONS OF PARAMETERS (cont'd)

VOLUME DEVELOPMENT (D_v)

An index to the shape of a lake basin that compares the shape to that of an inverted cone with a height equal to the maximum depth and a base equal to lake's surface area:

$$D_v = \frac{A(\bar{z})}{^1/_3 A(z_m)} = \frac{3\bar{z}}{z_m}$$

where,

D_v = volume development (dimensionless number)
$\bar{z}$ = mean depth of lake in m
z_m = maximum depth of lake in m
A = surface area of lake in m^2.

In a lake with a volume equal to this hypothetical cone, D_v = 1.0; a lake with a relatively greater volume would have an index >1.0; and a basin with a smaller volume than such a cone would have an index <1.0. From the above, it is apparent that the relationship of mean to maximum depth in the case of an ideal conical lake (D_v = 1.0), is 0.333. In the absence of more complete information, this ratio can be used to estimate mean depth from the maximum sounding.

SLOPE OF BASIN BETWEEN CONTOURS (S)

The degree of slope between two adjacent depth contours can be determined if the lengths of the two isobaths and the area enclosed by them are known. The slope (or tangent) is described by the formula:

$$S_{z_1,z_2} = \frac{L_{z_1} + L_{z_2}}{2} \bullet \frac{z_1 - z_2}{A_{z_1} - A_{z_2}} \bullet 100$$

where,

S_{z_1,z_2} = slope between depths z_1 and z_2 in percent (%)
z_1 = depth of first contour in m
z_2 = depth of second contour in m
L_{z_1} = length of first contour line in m
L_{z_2} = length of second contour line in m
A_{z_1} = area enclosed by first contour line in m^2
A_{z_2} = area enclosed by second contour line in m^2.

MEAN SLOPE (s)

An expression of the proximity of bathymetric contours to one another:

$$s = {}^1/_n\,({}^1/_2\,L_0 + L_2 + L_3\,...\,+ L_{n-1} + {}^1/_2\,L_n)\,\frac{z_{max}}{A} \bullet 100$$

where,

s = mean slope in percent (%)
L = length of each bathymetric contour line in m
n = total number contours on a bathymetric map, including the shore or zero contour
L_o = length of shore contour in m
L_n = length of deepest contour in m
L_{n-1} = length of next to the deepest contour in m
z_{max} = maximum depth in m
A = surface area of lake in m.

LENGTH OF CONTOUR LINES (L_z)

The linear distance of each contour line in m.

elevation of +0.5 to +0.6 m LWD (water depth of about 0.3 m during the survey). This depth appears to be particularly conducive to the development and dense growth of American water lotus beds (*Nelumbo lutea)*.

The lake lagoon is a small, elongated basin that appears to be the one most altered in recent years (Figure 2.9). It is now a tabular-shaped lagoon, extending in an east-west direction, with its outlet channel along the west side. Aerial photographs taken over the last 50 years show that it was once circular, when the barrier beach forming its north side was more than 100 m farther lakeward (Figures 5.6 and 5.7). The shore recession, resulting primarily from severe northeast storms, has taken place as overtopping waves wash barrier beach sand into the lagoon. The inlet channel through the barrier has also migrated to various positions since 1937.

The three basins are connected by narrow, relatively deep, channels that are the result of causeway constriction at the Conrail bridge (between the south and main basins) and at the U.S. Route 6 bridge (between the main and lake lagoon basins). The southerly channel is about 13 m wide with a maximum depth of -0.85 m LWD, whereas the northerly connecting channel is 18 m wide with a maximum depth of -1.68 m. The latter depth is the deepest sounding in the entire estuary.

WATER LEVELS

Figures 2.4 and 2.5 demonstrate the close correlation of estuary water levels and lake levels when the estuary inlet is open. During October 1989 and June-July 1990, the inlet was barred across, resulting in a considerably higher level in the estuary. As soon as the bar was breached (either by natural process or hand digging) the lake once again controlled the levels in the estuary as demonstrated by the close agreement of the records. Figure 5.8 shows how the lake has a strong (almost 1:1), direct influence on water levels in the estuary up to +1.1 m LWD. At levels higher than this in the estuary no relationship is indicated because the lagoon is barred off and the estuary acts as a lacustrine system.

Daily records of the open (stable) or barred closed (unstable) condition of the estuary mouth have been maintained since 1983 (Table 5.8). During the period 1983 to 1991 the inlet has been open 59% of the time (annual range 30-72%) and closed 41% (annual range 28-70%). Plots of mean daily water levels in Old Woman Creek estuary (such as Figure 2.4) show a marked seasonal trend: late in the year (October-December) the water level in the estuary builds up to >+1.5 m LWD at which stage the barrier is often breached artificially (digging); then December through about May-July the mean water level rises gradually to attain high levels over the summer until it breaches again. When it breaches, a classical "ebb tide delta" is built in Lake Erie off the inlet as sand from the barrier is deposited when velocities in the water exiting the estuary drop below the transport threshold. The rapid water level rise in the estuary in latter part of the year appears to be the result of the damming-effect of the barrier bar. Figures 2.6 and 2.7 indicate that neither precipitation nor runoff from the watershed are sufficient to totally account for the increase in water stored in the estuary in the months prior to the breach. Lake Erie waves, which frequently over top the barrier bar, may also supply a sizable quantity of water to the estuary during storms.

When the inlet is open (about 59% of the time), the primary hydrologic control for Old Woman Creek estuary is the level of adjacent Lake Erie. Both long- and short-term variations in lake level affect water levels in the estuary and thus may affect recent deposition, erosion, and biological processes. Even minor fluctuations in lake level on the order of a few centimeters can have profound effects in the estuary for two reasons: (1) the shallowness of the estuary makes it very responsive to fluctuations in water depth and (2) the elevation of the estuary floor is very near mean lake level.

Lake seiche events can be responsible for alternately exposing and flooding the entire floor of Old Woman Creek estuary. Several factors, however, tend to minimize the effects of seiche events on the long-term deposition of sediment in the estuary. First, many seiche events in Lake Erie are not directly transmitted into the estuary due to closure of the estuary mouth by the barrier bar. During the 17-year period (1983-1999), the mouth of the estuary was closed 41% of the time. If the duration and magnitude of seiche events are high, the likelihood of breaching the interceding barrier beach increases, allowing the estuary water level to fluctuate more directly with the lake. Second, the effects of seiche events in the estuary

Figure 5.6. Opened mouth of Old Woman Creek estuary in May 1949 (ODNR).

Figure 5.7. Closed mouth of Old Woman Creek estuary in July 1949 (Thomas H. Langlois).

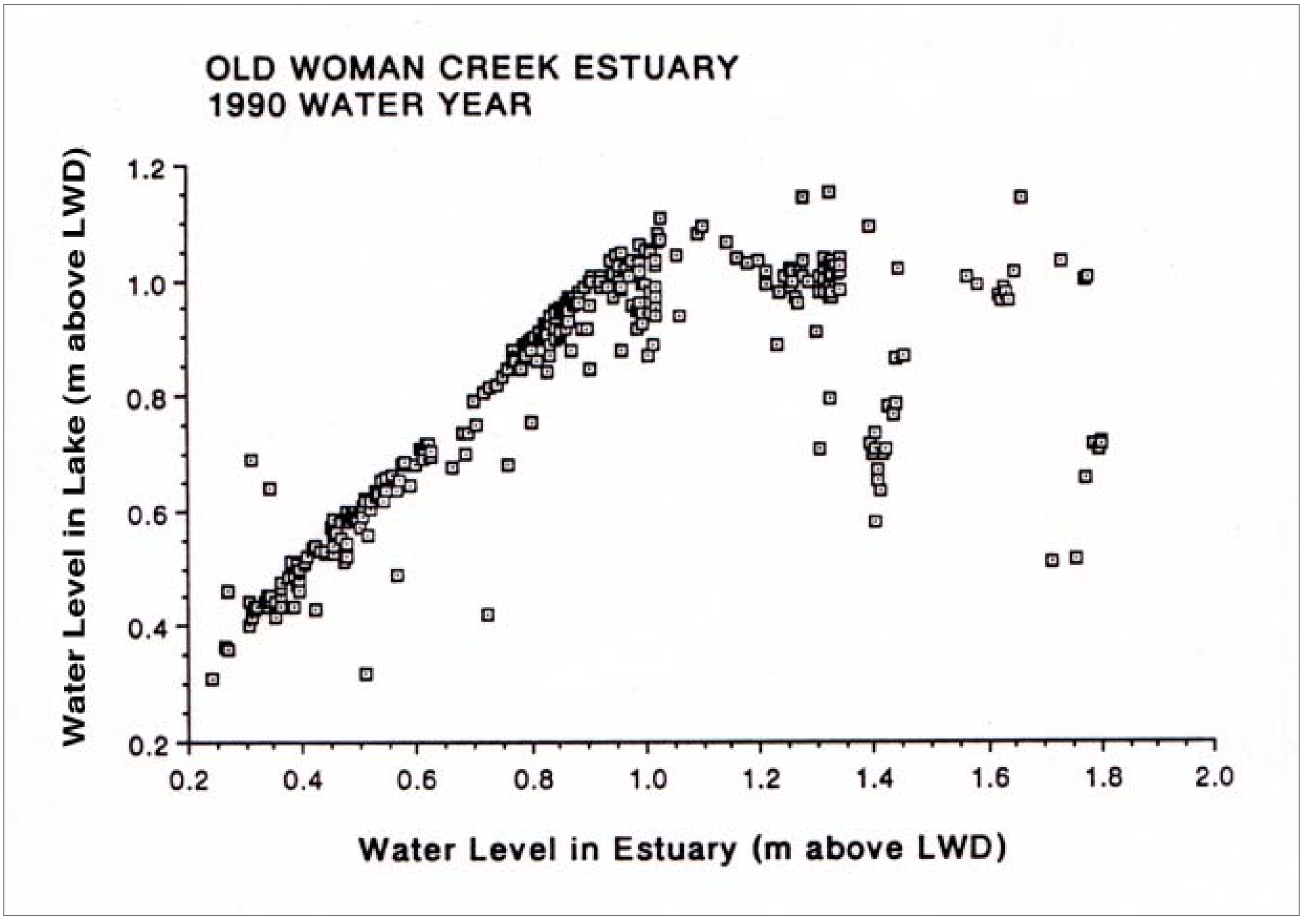


Figure 5.8. Correlation of Lake Erie and Old Woman Creek estuary water levels.

are limited by other factors. The duration of a seiche event is short (generally less than a 14-hour period). Further, the magnitude of the water-level fluctuations transmitted into the estuary may not be sufficient to generate flow through the estuary channel capable of disturbing sediments previously deposited. Finally, there may not be an influx of texturally different sediment to record the event. Despite these minimizing factors, Buchanan (1982) concluded that seiches are responsible for some of the erosional unconformities observed in the sediment record and may have provided opportunities for wind-generated wave action in the estuary to resuspend deposited sediment.

Table 5.11 presents the long term mean (1918 to 1996), maximum, and minimum monthly water levels for Lake Erie. These data show that the elevation of Lake Erie has a range of 1.6 m from the lowest levels recorded in the mid-1930s to the highest levels recorded in the mid-1980s. On a month-to-month basis, the lake tends to be lowest in winter and highest in late spring or early summer. The water budget for Lake Erie is composed of a number of factors which contribute to either inflow, outflow, or change in the amount of water stored in the lake.

Inflow Factors

- inflow from the Detroit River (80%)
- precipitation fall on the lake surface (11%)
- runoff from rivers in the lake basin (9%)

Outflow Factors

- outflow through Niagara River (88%)
- evaporation from the lake surface (8%)
- outflow via Welland Canal diversion (3%)
- consumptive use of water from lake (1%)

The difference between the inflow and the outflow is the change in storage, which in turn changes lake levels. Because of high spring runoff and low

TABLE 5.11. LAKE ERIE WATER LEVELS

	Maximum					Minimum					Mean			
	IGLD 1985		LWD		Year	IGLD 1985		LWD		Year	IGLD 1985		LWD	
	meters	feet	meters	feet		meters	feet	meters	feet		meters	feet	meters	feet
January	174.86	573.69	1.37	4.49	1987	173.21	568.27	-0.28	-0.93	1935	173.98	570.80	0.49	1.60
February	174.78	573.43	1.29	4.23	1987	173.18	568.18	-0.31	-1.02	1936	173.97	570.77	0.48	1.57
March	174.88	573.75	1.39	4.55	1986	173.20	568.24	-0.29	-0.96	1934	174.05	571.03	0.56	1.83
April	174.98	574.08	1.49	4.88	1985	173.38	568.83	-0.11	-0.37	1934	174.21	571.56	0.72	2.36
May	174.97	574.05	1.48	4.85	1986	173.44	569.03	-0.05	-0.17	1934	174.29	571.82	0.80	2.62
June	175.04	574.28	1.55	5.08	1986	173.45	569.06	-0.04	-0.14	1934	174.32	571.92	0.83	2.72
July	175.03	574.25	1.54	5.05	1986	173.45	569.06	-0.04	-0.14	1934	174.31	571.88	0.82	2.68
August	174.94	573.95	1.45	4.75	1986	173.43	569.00	-0.06	-0.20	1934	174.24	571.65	0.75	2.45
September	174.83	573.59	1.34	4.39	1986	173.38	568.83	-0.11	-0.37	1934	174.16	571.39	0.67	2.19
October	174.94	573.95	1.45	4.75	1986	173.30	568.57	-0.19	-0.63	1934	174.06	571.06	0.57	1.86
November	174.85	573.65	1.36	4.45	1986	173.20	568.24	-0.29	-0.96	1934	173.99	570.83	0.50	1.63
December	174.90	573.82	1.41	4.62	1986	173.19	568.21	-0.30	-0.99	1934	173.98	570.80	0.49	1.60
MEAN	174.92	573.84	1.43	4.67		173.32	568.63	-0.17	-0.57		174.13	571.29	0.64	2.09

Period of Record: 1918-1996

Data Source: U.S. Army Corps of Engineers, Detroit, MI, *Monthly Bulletin of Lake Levels for the Great Lakes* evaporation, storage of water in Lake Erie is highest in the spring. Levels are lowest in the fall and winter due to high evaporation and low runoff (Bolsenga and Herdendorf 1993).

Precipitation on the Lake Erie watershed contributes approximately the same amount of water into the lake as precipitation falling directly on the surface of the lake, however the watershed has a much larger surface area. Thus, if all the water that fell on the watershed ran into the lake, the runoff would contribute three times as much as precipitation over the lake. However, only about one-third of the rain falling on the watershed makes its way to the lake. The rest is lost to the air by evaporation from the soil or by transpiration from plants.

WATER STORAGE CAPACITY

In addition to size, depth, and configuration of the estuary, variations in lake level—attributable to regional climatic factors such as precipitation, evaporation, and runoff—are significant considerations when calculating the water storage capacity of the Old Woman Creek estuary. A model presented by Matisoff and Eaker (1989,1992) suggests the following flux rates for some of the hydrological factors influencing water storage in the estuary.

Flux Factors

- precipitation = 0.01 m^3/sec
- groundwater advection =0.00 – 0.07 m^3/sec
- seepage discharge (barrier beach) = 0.01 m^3/sec

They reported groundwater discharge velocities along the barrier sandbar, as calculated from seepage measurements, ranging from -0.007 m/day (recharge to estuary from Lake Erie) to 1.8 m/d (discharge to Lake Erie). Seepage measurements in the southern portion of the estuary ranged in velocity from 0 to 0.38 m/day into the estuary. These data yield flux calculations for groundwater advection to the estuary of near zero to 0.07 m^3/sec and a seepage discharge flux of near zero to 0.61 m^3/sec.

Mitsch, et al. (1989) devised a water budget for Old Woman Creek estuary using a catchment area of 68.6 km^2. They estimated the following water input and export fluxes for the estuary.

Inputs

- surface inflow = 0.18 m^3/sec
- precipitation = 0.01 m^3/sec

Exports

- evapotranspiration = 0.02 m^3/sec
- estuary discharge = 0.17 m^3/sec

Their surface inflow is equivalent to 0.0026 m^3/sec/km^2. This value compares favorably with Sandusky River inflow to Sandusky Bay at 0.0022 m^3/sec/km^2 and Portage River inflow to its estuary at 0.0017 m^3/sec/km^2 (Youngquist 1966). These estimates were made for the period March 1 through September 30, 1988. During this period, the water level in the estuary increased slightly, at a rate of about 700 m^3/day which accounts for the difference between inputs and exports.

Buchanan (1982) surveyed Old Woman Creek estuary in 1977 and calculated the average water depth at 0.3 m (water elevation = 174.4 m IGLD 1985 or +0.9 m LWD). He estimated the total volume of water in the estuary to be 113,000 to 127,000 m^3. A more detailed bathymetric survey by Herdendorf and Hume (1991) found that under same water level condition the estuary would hold approximately 146,500 m^3 of water.

Water storage in Old Woman Creek estuary is a function of the morphometry of the basins and the water level in the estuary. The water level, in turn, is primarily controlled by Lake Erie levels (when the inlet channel is open) or by catchment hydrologic factors (when the inlet is barred across). Typically the inlet is unstable (barred) over 41% of the time. The hydrologic factors which have a significant influence on water levels in the estuary include: (1) precipitation, (2) runoff, (3) evaporation, (4) groundwater advection, (5) seepage through the barrier bar and (6) wave overtopping of the bar. When the water level in the estuary is standing at the mean level for Lake Erie (+0.6 m LWD) the area and the volume of the estuary are 211,000 km^2 and 38,600 km^3, respectively.

WATERSHED DISCHARGE

Buchanan (1982), using a drainage basin area of 69.5 km^2, estimated the average discharge into the estuary at 0.43 m^3/sec or 0.006 m^3/sec/km^2. Based on an average concentration of suspended sediment of 0.1 g/l, he estimated that about 0.6 $g/m^3/sec$ of sediment enter the estuary. Within the estuary he found the average concentration of suspended sediment to be only 0.02 g/l or equivalent to 2.4 tons. Buchanan's estimates permit a retention time calculation of 7.3 days for water in the estuary based on precipitation records (Table 4.4). This value compares favorably with a flushing rate calculation of 8.5 days based on the water budget presented by Mitsch et al. (1989) and the estuary volume obtained by Herdendorf and Hume (1991). By extrapolating a surface inflow coefficient from the Sandusky River basin (0.002 $m^3/sec/km^2$), one obtains an average discharge rate of 0.15 m^3/sec for Old Woman Creek estuary which is equivalent to a flushing rate of 11.2 days.

Woods (1987) studied Old Woman Creek under storm conditions and measured a maximum discharge from Old Woman Creek to the estuary of 4.3 m^3/sec and a maximum sediment transport to the estuary of 411 g/sec for a brief period. He found that high discharges were not necessarily associated with high sediment concentrations. Land use activities, such as field preparation in the spring and cropping in the fall, heavily affected sediment concentrations in Old Woman Creek.

Worthy (1980) constructed a hydrograph for predicting runoff in the Old Woman Creek drainage basin. He used a watershed area of 78.7 km^2, an average drainage area slope equal to 4.85 m/km, and a basin length of 14.2 km. From the hydrograph he determined that a storm of 6 hours in duration and 1.73 inches of rainfall would yield a peak discharge of 18.3 m^3/sec. The peak discharge would occur in the creek 4.2 hours following the storm. Such a storm has a 5-year return period for the Old Woman Creek watershed.

Worthy (1980) concluded that the supply of sediment from the watershed does not have a significant effect on the stability of Old Woman Creek inlet. He found that the sediment being transported through the estuary was largely silt-and-clay-sized material, whereas the barrier beach is composed of medium sand, derived from erosion of adjacent lake bluffs. Using data from the Sandusky River watershed (50 km to the east), he extrapolated average suspended sediment load of 0.64 tons/day for Old Woman Creek. Thus, about 234 tons of sediment are transported to the estuary annually. He speculated that seiche activity keeps the estuary agitated and the sediment suspended so that the bulk of this material is carried through the inlet during periods of high flow when the inlet is stable (mouth open).

ESTUARY WATER QUALITY

Water quality monitoring has been conducted in Old Woman Creek Estuary since the early 1980s. The complete data records for this monitoring program are available at the Ohio Center for Coastal Wetlands Study located within the Old Woman Creek State Nature Preserve and National Estuarine Research Reserve. Currently this data is being assembled for publication as Old Woman Creek Technical Report No. 16, which will also be Contribution No. 6 to this Site Profile.

The means and ranges of the monitored parameters are presented in the following tables: Table 5.12 (Old Woman Creek at N & W Railroad bridge, Figure 1.6), Table 5.13 (upper Old Woman Creek estuary at Darrow Road bridge, Figure 1.4), Table 5.14 (lower Old Woman Creek estuary at mouth), and Table 5.15 (adjacent nearshore Lake Erie). The three year periods represent conditions at the inception of the monitoring program at Old Woman Creek (1981-1983), conditions during the last period of high water conditions at the estuary (1995-1997), and conditions during falling lake water levels (1998-2000). Figures 5.9 through 5.12 compare temperature, turbidity, soluble reactive phosphorus, and nitrate measurements in the estuary from the early 1980s with values for the late 1990s.

There were distinct differences between various chemical parameter means between the periods 1981 to 1983 and 1995 to 1997, particularly nitrate and silicate, but not for soluble reactive phosphorus (Figures 5.11 and 5.12). Despite these apparent differences, there was no statistical difference due to the very wide range of measured values during each of the two periods. These changes in water quality do not appear to be related to changing land use practices, but rather a consequence of either stagnation or free flow when the mouth of the estuary is either open or barred across, particularly during the summer months (Klarer 1999). In the 1981 to 1983 period, the mouth was closed during much of the summer, the result of diminished rainfall in the watershed. This decreased

TABLE 5.12. WATER QUALITY IN THE LOWER REACH OF OLD WOMAN CREEK AT THE N & W RAILROAD BRIDGE FOR THREE TIME PERIODS

Parameter		1981-1983	1995-1997	1998-2000
Temperature- ($^{\circ}C$)	mean	11.4	13.7	15.4
	range	-2.0-25.0	0.4-24.6	0.7-24.5
Dissolved Oxygen-mg/l	mean	9.5	8.9	7.7
	range	1.8-15.0	4.4-14.4	2.6-15.1
Specific Conductivity-µmhos/cm	mean	706	613	636
	range	389-1191	403-1117	317-1074
pH- Standard Units	mean	7.92	7.87	7.79
	range	7.50-8.45	7.52-8.55	7.11-8.62
Total Alkalinity-mg $CaCO_3$/l	mean	130	146	143
	range	64-238	93-207	60-212
Turbidity- NTU	mean	23.6	23.5	29.9
	range	2.4-150	2.9-300	1.6-354
Soluble Reactive Phosphorus-µg P/l	mean	31.4	28.9	41.5
	range	1.5-129.9	1.4-103.8	0.0-468.2
Total Phosphorus-µg P/l	mean	Not tested	115.2	122.1
	range	Not tested	13-707	4-571
Nitrate-mgN/l	mean	1.918	2.652	3.168
	range	0.012-7.578	0.0-6.354	0.008-15.153
Nitrite-µg N/l	mean	25.8	23.4	21.7
	range	1.0-191.9	1.6-129.7	0.0-196.7
Ammonia-mgN/l	mean	0.155	0.147	0.089
	range	0.001-1.472	0.008-0.840	0.015-0.526
Chloride-mgCl/l	mean	64.4	50.0	58.7
	range	27.8-129.0	19.0-129.6	15.3-130.4
Sulfate-mgSO_4/l	mean	65.7	65.9	63.4
	range	31.8-123.3	37.6 –154.3	22.5-128.9
Calcium-mg/l	mean	83.2	62.1	70.4
	range	45.0-158.3	37.2-104.2	33.4-159.8
Magnesium-mg/l	mean	18.1	16.1	17.6
	range	3.5-53.0	7.4-28.0	9.5-32.0
Sodium-mg/l	mean	31.8	30.9	37.6
	range	16.4-63.6	14.4-72.5	11.7-114.0
Potassium-mg/l	mean	6.0	6.4	7.1
	range	3.3-10.5	2.7-24.9	3.5-16.8
Iron- mg/l	mean	0.99	1.57	1.12
	range	0.04-2.99	0.18-34.10	0.17-11.22
Silicate- mgSi/l	mean	2.476	6.173	6.409
	range	0.286-10.427	1.404-9.492	1.610-12.652

TABLE 5.13. WATER QUALITY IN THE UPPER REACH OF OLD WOMAN CREEK ESTUARY AT DARROW ROAD BRIDGE FOR THREE TIME PERIODS

Parameter		1981-1983	1995-1997	1998-2000
Temperature- (°C)	mean	12.84	14.7	16.6
	range	-1.5-28	0.2-26.3	0.8-27.1
Dissolved Oxygen-mg/l	mean	8.63	8.46	7.07
	range	0.66-16.8	4.26-13.11	1.8-14.79
Specific Conductivity-µmhos/cm	mean	624	584	600
	range	346-1099	384-1023	298-929
pH- Standard Units	mean	7.91	7.83	7.78
	range	7.50-9.25	7.53-8.43	7.46-8.14
Total Alkalinity-mg $CaCO_3$/l	mean	131	150	146
	range	64-233	88-218	58-231
Turbidity- NTU	mean	30.1	29.2	47.5
	range	3.7-170	5.0-290	22-519
Soluble Reactive Phosphorus-µg P/l	mean	23.7	29.1	22.8
	range	0.4-121.8	1.7-120.1	0.0-206
Total Phosphorus-µg P/l	mean	Not tested	183.5	130.6
	range	Not tested	41-640	19-691
Nitrate-mgN/l	mean	1.890	2.585	3.110
	range	0.020-7.862	0.001-6.754	0.0-13.467
Nitrite-µg N/l	mean	41.7	30.6	34.7
	range	1.32-742.7	1.8-160.5	0-269.6
Ammonia-mgN/l	mean	0.176	0.204	0.118
	range	0.0-1.303	0.009-1.531	0.226-0.616
Chloride-mgCl/l	mean	57.99	43.2	49.3
	range	24.2-113.0	17.6-117.0	15.0-107.8
Sulfate-mgSO_4/l	mean	60.4	59.4	54.8
	range	30.6-98.3	30.4-150.4	21.8-124.9
Calcium-mg/l	mean	81.8	61.5	67.6
	range	49-140	40.9-102.7	31.2-120.7
Magnesium-mg/l	mean	17.9	16.1	17.0
	range	4.4-54.0	6.2-28.6	9.3-31.7
Sodium-mg/l	mean	30.2	27.7	31.9
	range	11.9-65.7	14.4-62.7	9.9-71.7
Potassium-mg/l	mean	6.2	6.5	6.9
	range	3.0-11.7	2.8-20.3	3.6-16.95
Iron- mg/l	mean	0.96	1.70	1.74
	range	0.04-3.25	0.31-23.3	0.22-9.35
Silicate- mgSi/l	mean	2.65	6.45	6.00
	range	0.310-8.87	2.00-10.21	1.22-10.17

TABLE 5.14. WATER QUALITY IN THE LOWER REACH OF OLD WOMAN CREEK ESTUARY AT THE MOUTH FOR THREE TIME PERIODS

Parameter		1981-1983	1995-1997	1998-2000
Temperature- (°C)	mean	13.0	16.0	18.2
	range	-3-32	0.2-28.6	1.9-29.7
Dissolved Oxygen-mg/l	mean	9.3	8.7	6.69
	range	3.6-15.0	2.5-13.4	2.68-15.64
Specific Conductivity-μmhos/cm	mean	431	397	448
	range	250-1096	263-524	268-771
pH- Standard Units	mean	8.03	7.97	7.89
	range	7.45-8.90	7.46-8.64	7.50-8.61
Total Alkalinity-mg $CaCO_3$/l	mean	112	118	126
	range	57-230	84.1-193	84-202
Turbidity- NTU	mean	32	30	53
	range	4-99	6.7-78	3.3-279
Soluble Reactive Phosphorus-μg P/l	mean	12.0	15.7	9.9
	range	0.0-89.2	1.7-100.8	0.0-98.7
Total Phosphorus-μg P/l	mean	Not tested	214	152
	range	Not tested	39-1232	21-357
Nitrate-mgN/l	mean	1.159	1.119	1.209
	range	0.009-28.594	0.0-5.271	0.0-8.564
Nitrite-μg N/l	mean	24.6	27.8	23.3
	range	0.6-144.6	0.8-152.8	0.11-99.0
Ammonia-mgN/l	mean	0.189	0.315	0.168
	range	0.001-1.149	0.009-1.745	0.019-1.073
Chloride-mgCl/l	mean	30.6	23.3	30.0
	range	10.7-112.5	12.0-37.8	8.3-77.3
Sulfate-mgSO_4/l	mean	29.8	31.3	33.9
	range	11.2-78.0	11.1-62.6	16.7-112.7
Calcium-mg/l	mean	59.1	43.2	49.8
	range	36.0-116.3	27.3-64.6	26.5-85.9
Magnesium-mg/l	mean	12.4	11.3	13.5
	range	3.2-37.0	6.0-16.0	8.2-28.9
Sodium-mg/l	mean	17.2	16.1	19.9
	range	8.1-37.7	9.3-24.0	7.8-57.6
Potassium-mg/l	mean	3.8	4.6	5.3
	range	0.2-7.6	1.8-8.7	2.2-13.1
Iron- mg/l	mean	1.13	1.51	1.86
	range	0.02-5.60	0.32-7.11	0.22-9.50
Silicate- mgSi/l	mean	1.075	3.187	2.935
	range	0.025-4.031	0.320-8.340	0.0-9.550

TABLE 5.15. WATER QUALITY IN NEARSHORE LAKE ERIE OFF OLD WOMAN CREEK ESTUARY MOUTH FOR THREE TIME PERIODS

Parameter	1981-1983	1995-1997	1998-2000
Temperature- (°C) mean	13.9	15.9	17.1
range	-5 to 28	.8 to 27.3	2.3-26.5
Dissolved Oxygen-mg/l mean	9.5	9.3	9.0
range	3.4 to 14.5	4.9 to 14.1	6.5-14.5
Specific Conductivity- µmhos/cm mean	313	286	297
range	250-607	248-348	252-534
pH- Standard Units mean	8.24	8.13	8.18
range	7.75 to 8.72	7.78 to 8.64	7.8-8.75
Total Alkalinity-mg $CaCO_3$ /l mean	90.5	90.2	89
range	49 to 134	76 to 103	77-114
Turbidity- NTU mean	25	18.3	30
range	1 to 79	2.2 to 70	1.2-242
Soluble Reactive Phosphorus-µg P/l mean	8.4	11.1	10.3
range	0.0 to 45	0.7 to 35.4	0.0-221.3
Total Phosphorus-µg P/l mean	Not determined	100	68
range	Not determined	21 to 366	14-396
Nitrate-mgN/l mean	0.392	0.666	0.753
range	0.0 to 2.333	0.0 to 3.606	0.0-6.342
Nitrite-µg N/l mean	12.8	11.7	10.2
range	1 to 52.7	3.8 to 28.2	0.9-35.8
Ammonia-mgN/l mean	0.106	0.146	0.071
range	0.0 to .715	.001 to .884	0.007-0.603
Chloride-mgCl/l mean	16.5	13.9	14.4
range	4.6 to 65.9	8.9 to 22.2	3.2-60.2
Sulfate-mgSO_4/l mean	19.4	22.0	22.5
range	10.5 to 49.1	14.4 to 37.9	13.8-51.8
Calcium-mg/l mean	43.1	32.7	33.4
range	24.2 to 82.5	26.9 to 42.4	20.7-50.5
Magnesium-mg/l mean	10.4	8.1	9.5
range	2.0 to 25.5	3.4 to 13.1	7.1-15.1
Sodium-mg/l mean	12.2	10.9	10.7
range	8.0 to 32.7	7.8 to 15.3	7.6-24.7
Potassium-mg/l mean	2.6	3.2	3.5
range	1.7 to 6.2	2.1 to 6.2	2.0-18.2
Iron- mg/l mean	0.75	0.76	1.12
range	0.01 to 4.09	0.07 to 3.29	0.04-9.4
Silicate- mgSi/l mean	0.510	1.530	1.320
range	0.041 to 3.659	0.002 to 3.606	0.034-8.169

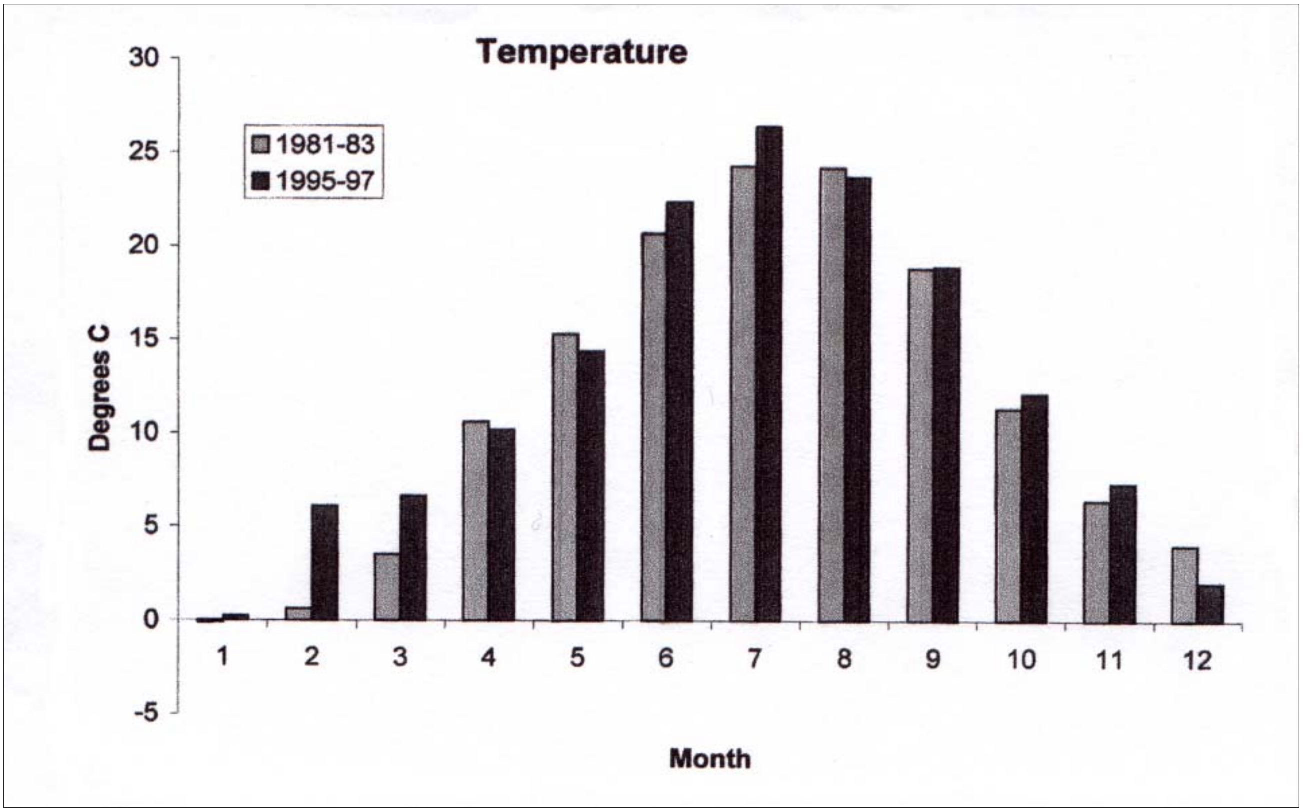


Figure 5.9. Trends in temperature for Old Woman Creek estuary.

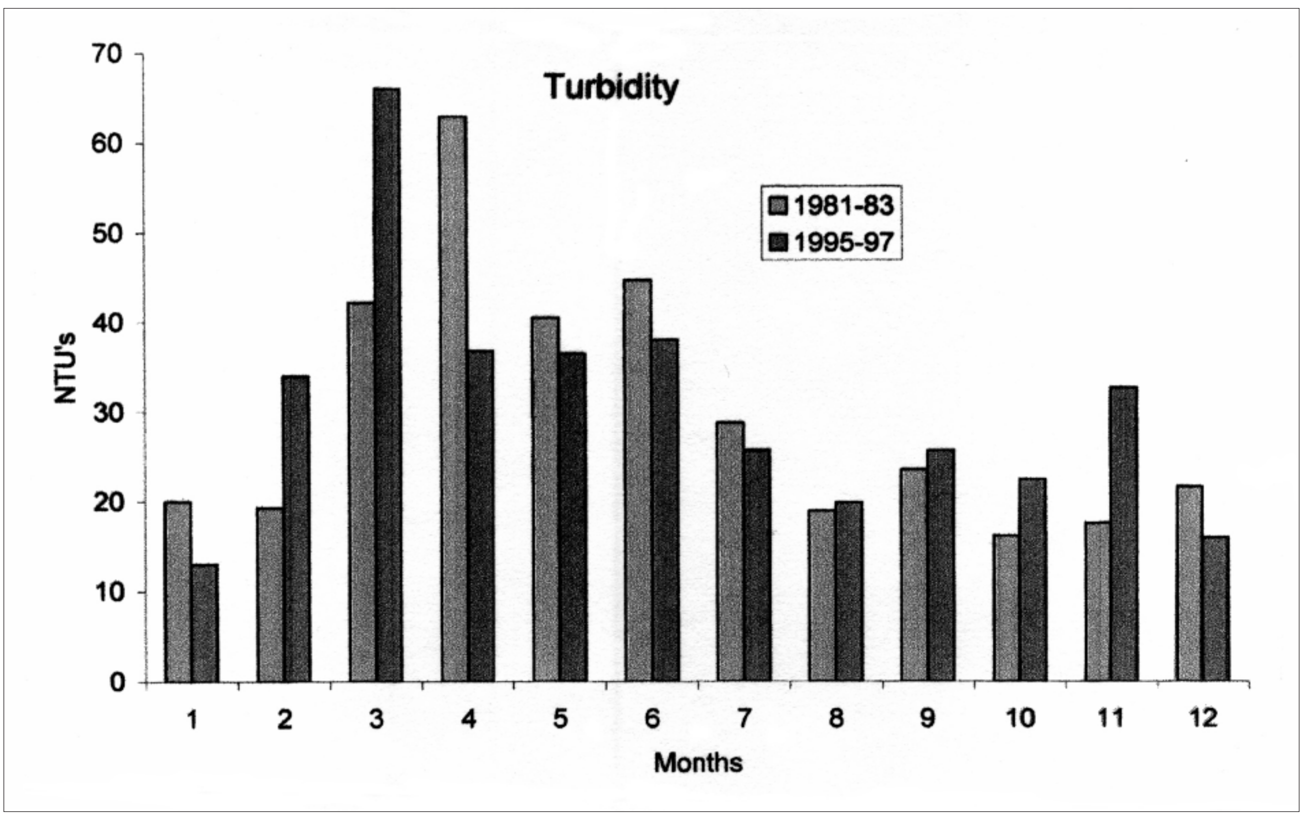


Figure 5.10. Trends in turbidity for Old Woman Creek estuary.

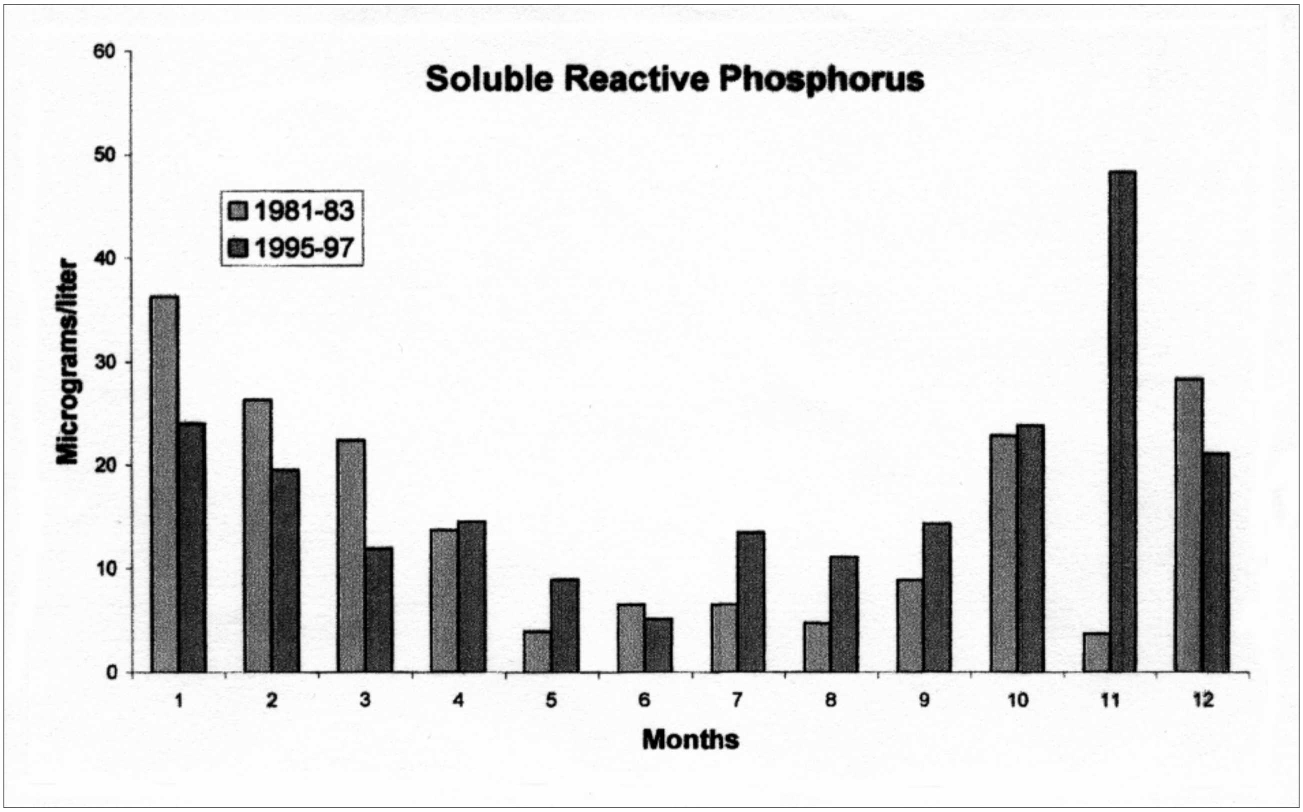


Figure 5.11. Trends in soluble reactive phosphorus concentrations for Old Woman Creek estuary.

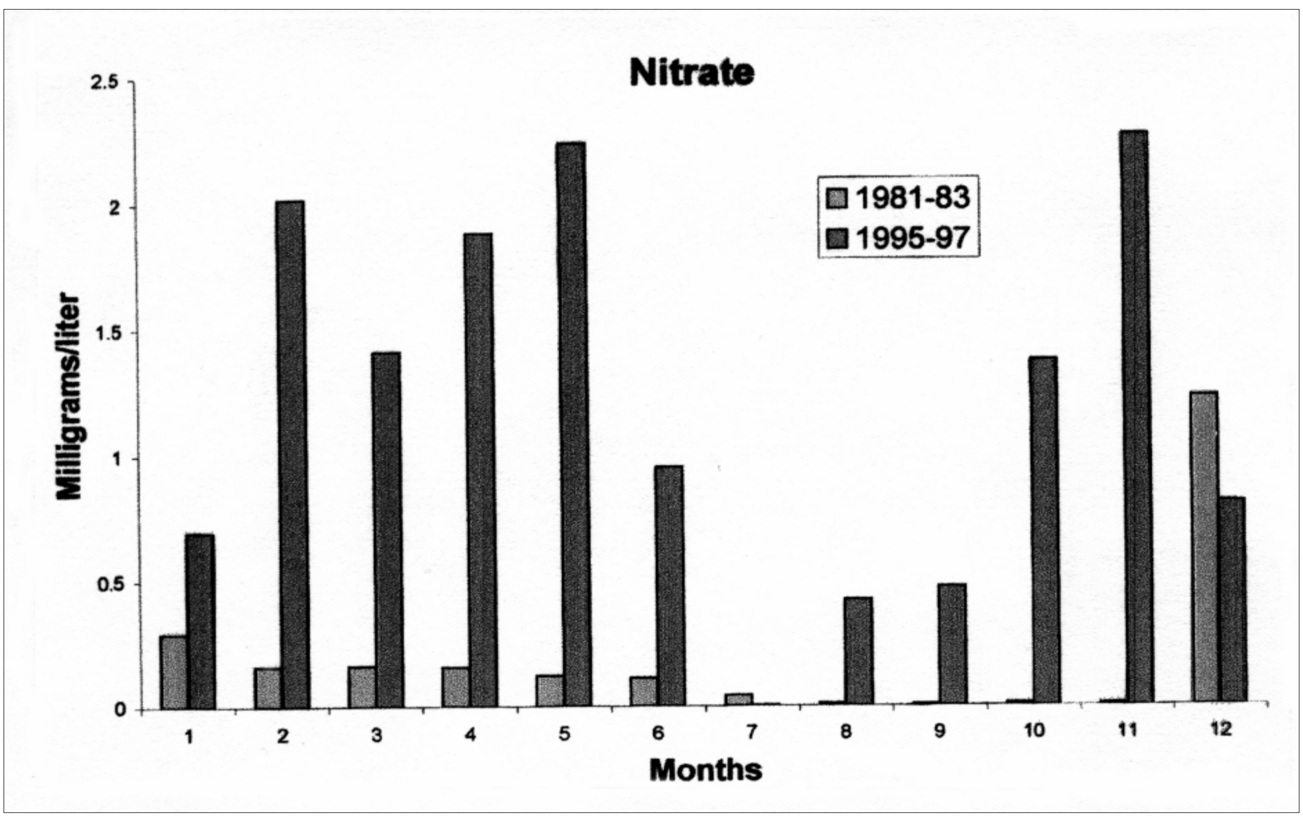


Figure 5.12. Trends in nitrate concentrations for Old Woman Creek estuary.

rainfall resulted in the transport of nutrients of lower concentrations into the estuary. With decreased rainfall, the input of groundwater—which remains fairly constant during most conditions—became more significant. The concentrations of chemicals associated with groundwater inflow, such as calcium, increased. The changes in the chemical composition of the estuary related to declining Lake Erie water levels (1995 to 1997 verses 1998 to 2000) do not appear to be as great as those associated with the opening (1995 to 1997) and closing (1981 to 1983) of the estuary mouth.

The addition of automated data loggers to the monitoring program in 1995 resulted in a more detailed understanding of the daily, weekly, and monthly changes in the chemistry and biology of the estuary. Figure 5.13 is an example of the diurnal fluctuations in oxygen levels that are now being recorded.

ESTUARY MIXING

Several investigations have demonstrated the encroachment of Lake Erie water into coastal estuaries and the subsequent mixing of lake and tributary water. Herdendorf (1965) noted a fourfold decrease in specific conductance of Cuyahoga River water in its estuary as it mixed with and was diluted by lake water. Schroeder and Collier (1966), also studying the Cuyahoga water quality, found that colder and less mineralized lake water intruded under warmer and more contaminated river water. They concluded that the extent of the intrusion was affected by seiches, wind, and fluctuations in both streamflow and lake level. Surveys and water level comparisons showed similar characteristics in the Maumee River estuary with distinct intrusions of lake water that mixed with river water for 10 km upstream (Herdendorf 1970). Current

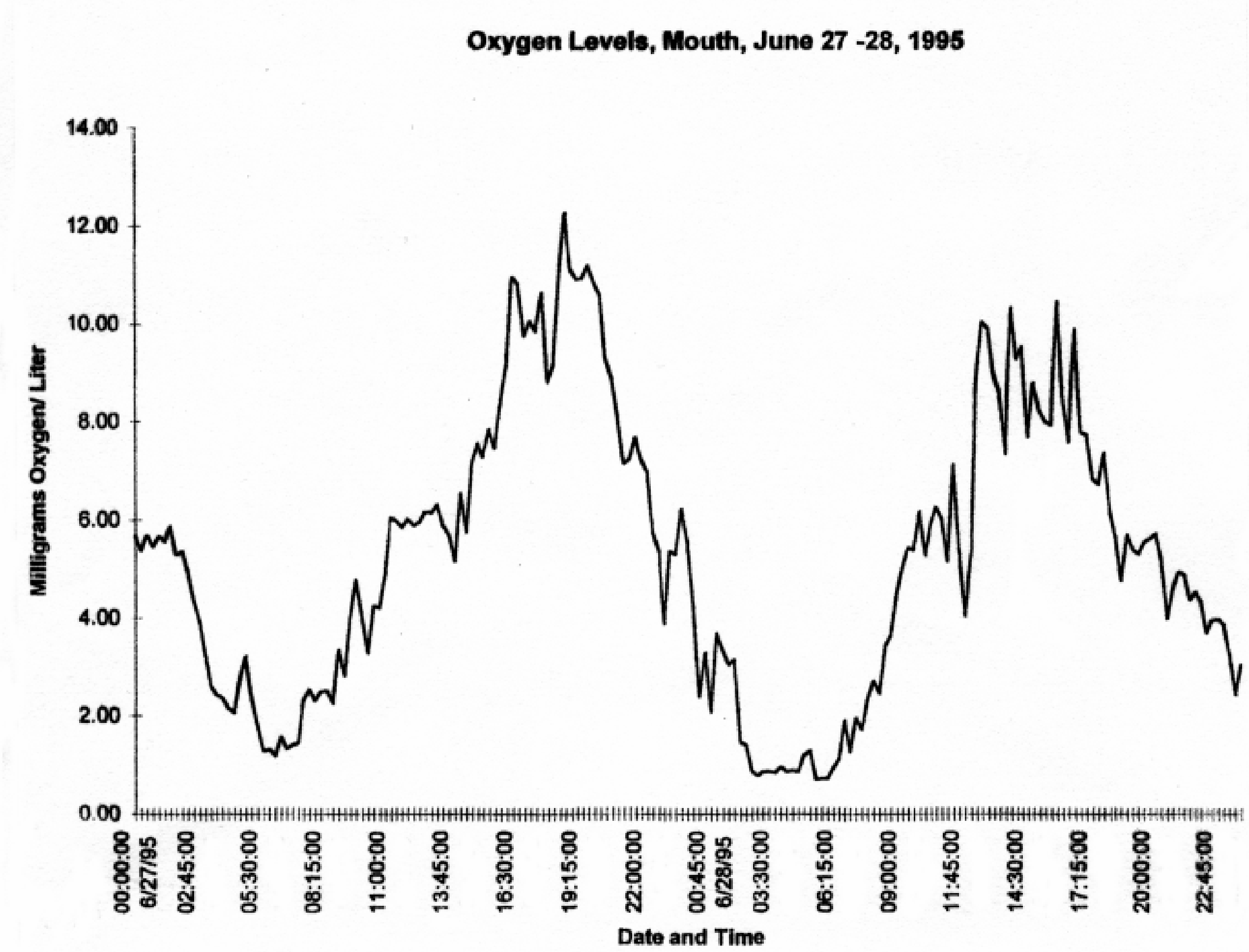


Figure 5.13. Example of dissolved oxygen monitoring in Old Woman Creek estuary.

measurements mid-way along the estuary yielded an upstream flow at all depths under the stress of a 25 km/hr wind from the northeast. Bedford (1989) contrasted transport mechanisms in Lake Erie tributaries to those operating in marine estuaries and concluded that although there is negligible propagation of lunar-solar driven tidal waves, there are transport analogies within Lake Erie estuaries associated with meteorologically induced water level fluctuations and chemical gradients. Krieger (1993) developed a method for estimating fluxes of materials from estuarine wetlands into Lake Erie using Old Woman Creek as a demonstration example. The method requires frequent measurements of atmospheric deposition, precipitation, evaporation, upstream tributary discharge, estuary water level changes, and water chemistry at upstream and downstream locations, as well as a knowledge of estuary depth-area and depth-volume relationships.

ESTUARY AS A CHEMICAL SINK AND TRANSFORMER

Klarer and Millie (1989) studied the role of the Old Woman Creek estuary in ameliorating storm water that passed through it. Storm water caused one of three possible changes in the concentration of individual chemical species. Possibility 1— if a chemical was fairly insoluble or bound to the sediment, then its concentration went up with the input of the surface runoff phase of storm water, as did orthophosphate (Figure 5.14). Maximum water inflow and maximum sediment input (turbidity) is associated with this surface runoff phase (Baker 1984). Possibility 2—if the chemical was soluble, it percolated into the ground and entered the creek with the interflow, after the initial influx of the sediment-rich storm water. Nitrate (Figure 5.14) followed this pattern. Possibility 3—if a chemical entered the creek at a constant rate, such as in groundwater, the concentration of this chemical decreased with the influx of storm water. For example, calcium displayed this pattern of distribution during storm runoff events (Figure 5.14).

Inflow-outflow ratios of chemical concentrations were used to estimate the estuary's relative effectiveness in modifying water passing through it (Klarer and Millie 1989). The results showed that 12 to 60% of the metals and 35 to 80% of the biologically-important nutrients were retained within the estuary. They attributed the amelioration of storm-water quality to sedimentation, biological uptake, and geochemical processes. Similarly, Heath (1986) determined that water leaving Old Woman Creek estuary had a 77% lower concentration of soluble reactive phosphorus than water entering the estuary, while Klarer (1988) found that nitrate and silicate concentrations were reduced 42% and 49%, respectively. In another study of Old Woman Creek estuary, Reeder and Mitsch (1989a) found that conductivity, turbidity, and total suspended solids generally had the highest concentrations at the upstream inflow, then decreased as much as sevenfold as the water transited the estuary.

Krieger (2001) has shown that Old Woman Creek estuary receives chemically-laden water from its tributaries and that the estuary's wetlands function as sink and transformer of most incoming materials and thereby substantially reducing the impact of those materials on the chemistry and biology of the receiving water body, Lake Erie. Figure 5.15 presents a model that demonstrates the processes involved. Water carries dissolved and particulate materials into the estuary via several pathways in: (1) surface runoff from the watershed, (2) intrusions of lake water during seiches and storm surges, (3) direct precipitation, (4) groundwater flow, and (5) wind-borne dry deposition. Water and associated materials are exported from the estuary via: (1) outflow to the lake, (2) groundwater seepage at the barrier bar, and (3) evaporation and volatilization. Biota, such as fish and waterfowl, may also provide important routes of materials input and export for the estuary. In his 3-year study, Krieger (2001) measured the major nutrients and agricultural pollutants entering and leaving the estuary. Table 5.16 presents the monthly averages of several water quality parameters for the 1990 water year (October 1989 through September 1990). He found that phosphorus and nitrate/nitrite nitrogen showed significant reduction as water passed through the estuary (Table 5.17). Of 12 herbicides analyzed, only four (alachlor, atrazine, metolachlor, and metribuzin) were consistently detected, and their concentrations were substantially lower at the outlet than upstream.

Krieger (2001) noted that both the ammonia and total Kjeldahl nitrogen loads leaving the estuary were greater than those entering, thus suggesting that ammonification may be a major process within the estuary. Wickstrom (1988) also reported elevated ammonia concentrations in the water flowing out of the estuary. When analyzing total nitrogen loading data

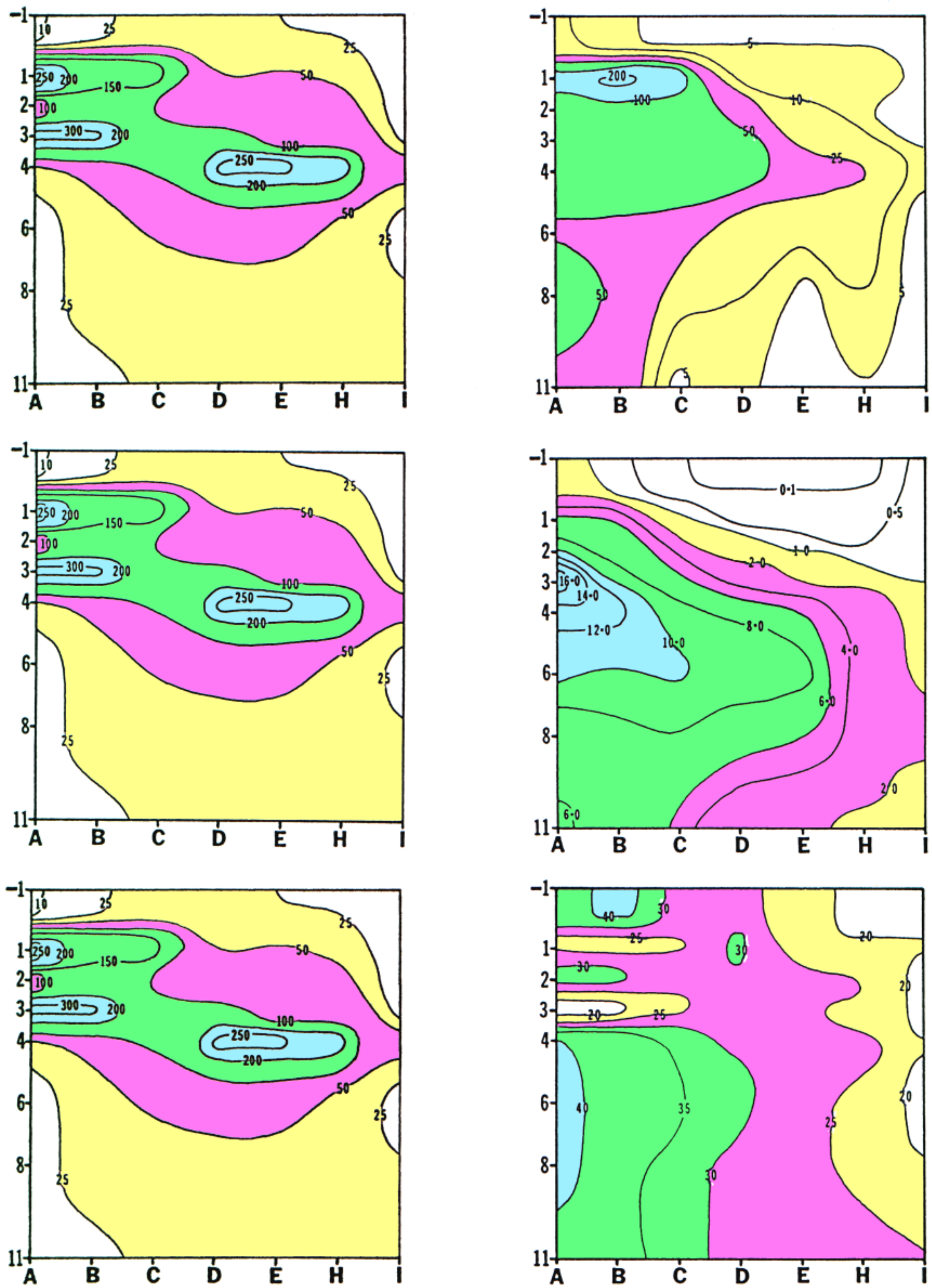


Figure 5.14. Impact of storm water passage on the concentration of selected chemicals in Old Woman Creek estuary.

NOTE: Turbidity (NTU), on the left side of the diagram, represents the passage of storm water; right side—soluble reactive phosphorus (upper), nitrate (center), calcium (bottom). Vertical scale on each graph is day after rainfall event; horizontal scale is sampling sites from above the estuary (A) to nearshore Lake Erie (I).

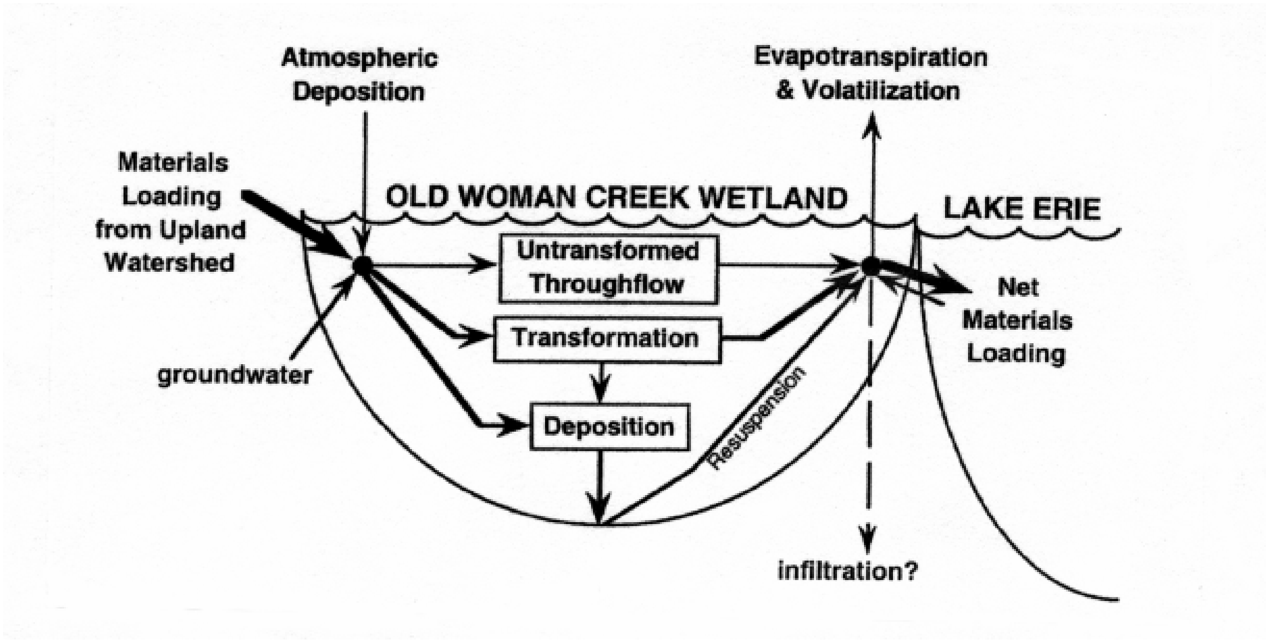


Figure 5.15. Conceptual model of materials fluxes in Old Woman Creek estuary wetlands (Krieger 2001).

(nitrate/nitrite and total Kjeldahl nitrogen) for water year 1990, Krieger found that about 14% of the nitrogen that flowed into the estuary did not enter Lake Erie (Table 5.17). Tomaszek et al. (1997) measured denitrification rates in the Old Woman Creek estuary sediments. The rates they reported support the hypothesis that the denitrification process could be a major sink for nitrogen in this estuary. Lavrentyev et al. (1998) examined the nitrogen dynamics of the microbial plankton communities. Although they were unable to estimate ammonia cycling rates, because of large ammonium concentrations in the water from storm runoff during their sampling periods, their preliminary data suggest that ammonium recycling in these plankton communities may be significant, particularly during periods of summer-stagnation.

An average nitrogen:phosphorus (N:P) ratio of 29.67 suggested that the phytoplankters in the estuary were P-limited (Heath 1992a,b). However, there was no evidence of P-limitations in the nutrient enrichment studies of Heath (1987). In addition, phosphatase specific activity, an indicator of P-limitation, also remained low during the study period. Heath (1987,1992a,b) reported that there was some evidence that N-availability may, on occasion, be limiting; but, he felt that light probably was the most important limiting factor for the phytoplankton in the estuary .

Organic pollution, including agricultural pesticides, in the Great Lakes is a growing major concern (Brody et al. 1998). The role of the estuary in mitigating organic pollution, particularly herbicides and pesticides has been examined by Chin et al. (1998), Everett et al. (1999), and Miller and Chin (2002). Their work has demonstrated the role of nitrates and naturally-occurring organic matter in serving as photosensitizers to enhance the photolytic breakdown of the pesticide carbaryl and the herbicide alachlor, both widely used agrochemicals in the midwest. The present authors anticipate that wetland areas such as Old Woman Creek estuary may play a significant role in the mitigation of this pesticide problem.

Marine estuaries have been found to be important in improving the quality of riverine water flowing through them to the ocean (Kennedy 1984). Physical, geochemical, and biochemical processes are all important in removing both suspended and dissolved chemicals from the water in these estuaries. Physical and geochemical processes are usually most effective in the area of the upper estuary, termed the "turbidity maximum," where suspended sediment concentrations are much higher than in surrounding waters (Schubel and Pritchard 1986). Biochemical processes are most evident in the lower estuary, because this is the area of greatest biological activity (Sharp et al. 1984).

TABLE 5.16. OLD WOMAN CREEK AND ESTUARY WATER QUALITY: 1990 WATER YEAR

	Oct	Nov	Dec	Jan	Feb	Mar
Water Discharge (m^3/s)						
Old Woman Creek	0.15	0.61	0.13	2.40	2.13	0.19
Estuary	0.24	0.61	0.13	2.08	2.64	0.15
Conductivity (µmhos at 25°C)						
Old Woman Creek	831	744	855	667	542	631
Estuary	536	585	847	646	504	428
Total Suspended Solids (mg/l)						
Old Woman Creek	12.8	19.6	2.3	23.0	37.1	8.1
Estuary	45.5	115.2	29.2	62.1	72.7	66.2
Chloride (mg/l as Cl^-)						
Old Woman Creek	96.3	72.2	85.1	60.5	46.1	53.7
Estuary	45.2	48.5	81.4	58.6	41.5	30.2
Soluble Reactive Phosphorus (µg/l as P)						
Old Woman Creek	16	14	10	9	14	4
Estuary	7	7	10	5	11	4
Total Phosphorus (µg/l as P)						
Old Woman Creek	71	90	30	77	100	28
Estuary	150	191	76	107	133	83
Nitrate + Nitrite (mg/l as N)						
Old Woman Creek	3.93	3.86	3.94	7.23	5.93	4.25
Estuary	0.37	2.44	3.94	6.63	5.28	2.39
Ammonia (mg/l as N)						
Old Woman Creek	1.17	0.48	0.51	0.19	0.13	0.15
Estuary	0.20	0.39	0.51	0.24	0.05	0.11
Total Kjeldahl Nitrogen (mg/l as N)						
Old Woman Creek	1.81	1.12	1.00	0.84	0.81	0.66
Estuary	1.52	1.51	1.29	0.99	0.96	0.75
Soluble Reactive Silica (mg/l as SiO_2)						
Old Woman Creek	5.98	7.51	6.84	7.96	7.15	4.74
Estuary	3.98	6.19	5.87	7.51	6.29	3.40

Data Source: Krieger (2001)

TABLE 5.16. OLD WOMAN CREEK AND ESTUARY WATER QUALITY: 1990 WATER YEAR (cont'd)

	Apr	May	Jun	Jul	Aug	Sep	Mean
Water Discharge (m^3/s)							
Old Woman Creek	1.25	0.82	0.04	0.20	0.08	0.74	0.71
Estuary	1.28	0.77	0.00	0.18	0.05	0.59	0.71
Conductivity (µmhos at 25°C)							
Old Woman Creek	586	584	708	714	639	640	678
Estuary	496	391	520	512	354	381	517
Total Suspended Solids (mg/l)							
Old Woman Creek	30.7	71.3	19.2	25.1	29.4	37.1	26.3
Estuary	116.7	126.9	75.2	67.9	52.9	64.7	74.6
Chloride (mg/l as Cl^-)							
Old Woman Creek	45.9	42.9	70.3	70.3	63.2	54.6	63.4
Estuary	35.2	22.6	38.6	38.7	20.8	22.1	40.3
Soluble Reactive Phosphorus (µg/l as P)							
Old Woman Creek	8	9	11	13	16	30	12.8
Estuary	7	4	3	4	5	8	6.3
Total Phosphorus (mg/l as P)							
Old Woman Creek	57	130	63	70	98	183	83.1
Estuary	157	174	230	184	143	170	149.8
Nitrate + Nitrite (mg/l as N)							
Old Woman Creek	4.20	5.56	2.53	7.05	1.65	3.48	4.47
Estuary	3.16	2.85	0.41	0.92	0.42	1.00	2.48
Ammonia (mg/l as N)							
Old Woman Creek	0.13	0.16	0.06	0.08	0.10	0.12	0.27
Estuary	0.19	0.22	0.15	0.24	0.14	0.16	0.22
Total Kjeldahl Nitrogen (mg/l as N)							
Old Woman Creek	0.82	1.12	0.67	0.74	0.80	0.93	0.89
Estuary	1.22	1.38	1.49	1.66	1.16	1.19	1.26
Soluble Reactive Silica (mg/l as SiO_2)							
Old Woman Creek	4.63	5.26	5.11	7.30	7.50	8.43	6.53
Estuary	4.37	2.94	0.98	1.41	2.48	4.34	4.15

Data Source: Krieger (2001)

TABLE 5.17. COMPARISON OF MATERIALS LOADING FROM TRIBUTARIES TO OLD WOMAN CREEK ESTUARY WITH DISCHARGE FROM THE ESTUARY TO LAKE ERIE: 1990 WATER YEAR

Component	To OWC Estuary	To Lake Erie	Retained in Estuary
Water Discharge	22.5 x 10^6 m^3	22.4 x 10^6 m^3	0.3 %
Total Suspended Solids	2.70 x 10^6 kg	3.01 x 10^6 kg	-11.5 %[1]
Chloride (Cl^-)	0.97 x 10^6 kg	1.00 x 10^6 kg	-3.0 %[2]
Total Phosphorus (P)	5,831 kg	3,867 kg	33.5 %
Soluble Reactive Phosphorus (P)	521 kg	283 kg	45.7 %
Nitrite/Nitrate Nitrogen (NO_{2+3}-N)	136,733 kg	107,610 kg	21.3 %
Ammonia Nitrogen (NH_3-N)	3,255 kg	6,234 kg	-91.8 %[3]
Total Kjeldahl Nitrogen (organic N)	30,123 kg	35,093 kg	-16.5 %[4]
Soluble Reactive Silica (SiO_2)	154,104 kg	145,121 kg	5.8 %

NOTES:

1. Total suspended solids load increased during passage through the estuary, although most inorganic particles settle out of the water column upon entering the estuary, because plankton is produced throughout the estuary and upon export more than compensates for the sedimentation loss.

2. A small increase in the amount of chloride exported from the estuary may reflect the use of salt for ice control on the bridges crossing the estuary and groundwater contributions within the estuary.

3, 4. More ammonia and organic nitrogen left the estuary than entered, with the net export enlarged by storms, which may reflect the release of transformed nitrite/nitrate nitrogen to ammonia and organic compounds by storm-induced resuspension of anaerobic, organic-rich sediment of the estuary.

Data Source: Krieger (2001)

The general physical, geochemical, and biological pollution reduction processes are similar in both marine estuaries and Old Woman Creek estuary (Klarer 1988). However, unlike marine estuaries, there is no specific "turbidity maximum" in the upper part of the estuary. In Old Woman Creek, the lower estuary may partially serve as this "turbidity maximum." Here, the estuary is very shallow and has a very high surface area to volume ratio. Even moderate winds re-suspend the bottom sediments, creating high turbidity areas which facilitate these physical and geochemical processes. Like marine estuaries, biological activity is highest in the lower estuary of Old Woman Creek.

WATERSHED HYDROLOGY

Streams tributary to Lake Erie, such as Old Woman Creek above its estuary, are characterized by a continual downstream movement of water, dissolved substances, and suspended particles, as well as bedload sediments during periods of high flow. These components are derived primarily from the stream's watershed—the total land area (69 km^2) draining into the channel of Old Woman Creek. Hence, the hydrological, chemical, and biological characteristics of Old Woman Creek reflect the climate, geology, and vegetational cover of the watershed along with the human land use activities within the drainage basin.

Water in the channel of streams originates from: (1) direct precipitation, (2) overland or sheet runoff, and (3) subsurface flow (Wetzel and Likens 1979). When water is added to the surface of the watershed's soil at a rate that exceeds the soil's infiltration capacity, it runs overland as sheet flow. Overland runoff plus water that soaks into the soil and flows laterally to the stream channel are the main components of peak flow or floods. Permeable soils tend to become saturated with water below a certain depth. The surface of this saturated zone is known as the water table; water in the soil above the water table is termed vadose water, while that below is called groundwater. During the dryer portions of the year, groundwater provides a relatively stable base flow component in Old Woman Creek.

STREAM ORDER

The Horton-Strahler method of ordering the tributaries to a stream (Horton 1945, Strahler 1952) provides a way of analyzing the bifurcations of a stream and comparing the complexity of one watershed to another. In this method each headwater or finger-tip tributary (including ephemeral and intermittent streams) is designated as the first order. Two first-order tributaries combine to produce a second-order tributary, two second-order tributaries produce a third, and so on. Only the union of two tributaries of equal order can produce a higher order, thus the order of the trunk stream is not changed below the confluence with a stream of lower order. Generally, the diversity and abundance of aquatic organisms in a stream increases as its order increases. Table 5.18 gives a summary of stream orders for Old Woman Creek. At its estuary, Old Woman Creek is an fourth-order tributary to Lake Erie.

SURFACE DRAINAGE AREA

The network of tributaries in the Old Woman Creek watershed forms a dendritic (tree-like) drainage pattern (Figure 5.16). The boundaries of the drainage basin were determined from surface features (topographic divides) depicted on U.S. Geological Survey topographic maps, soils maps, and aerial photographs. The total surface drainage area is 69 km^2. The drainage density for the watershed (total stream length/area of drainage basin) is 1.1 km/km^2.

SUBSURFACE DRAINAGE AREA

Subsurface flow may have different boundaries (phreatic divides), particularly in areas underlain with soluble or permeable deposits (Wetzel and Likens 1979). This is the case for Old Woman Creek where the subsurface drainage basin is dramatically larger than the surface watershed by virtue of a major glacially buried valley that underlies the estuary and extends over 70 km to the south. Preglacial bedrock topography was used to define the boundaries of the subsurface drainage basin (Figure 5.17). This yields a potential subsurface drainage area of approximately 2,500 km^2. Because the bedrock floor of the preglacial valley lies some 40 m below the bed of the estuary, it is likely that much of the groundwater flow in the buried valley is beneath the creek channel and therefore does not influence the hydrologic regime of Old Woman Creek. However, if the elevation of the deepest part of the channel in the estuary is extended laterally until bedrock is encountered, a more reasonable estimate is obtained for a subsurface drainage area that interacts with Old Woman Creek estuary. This effective subsurface drainage area is approximately 100 km^2.

TABLE 5.18. STREAM ORDERS FOR OLD WOMAN CREEK TRIBUTARIES

Order	Number	Mean Length (km)	Total Length (km)
1st	28	1.4	42.0
2nd	6	3.1	18.2
3rd	2	4.8	9.5
4th	1	5.3	5.3
Total	37	2.0	75.0

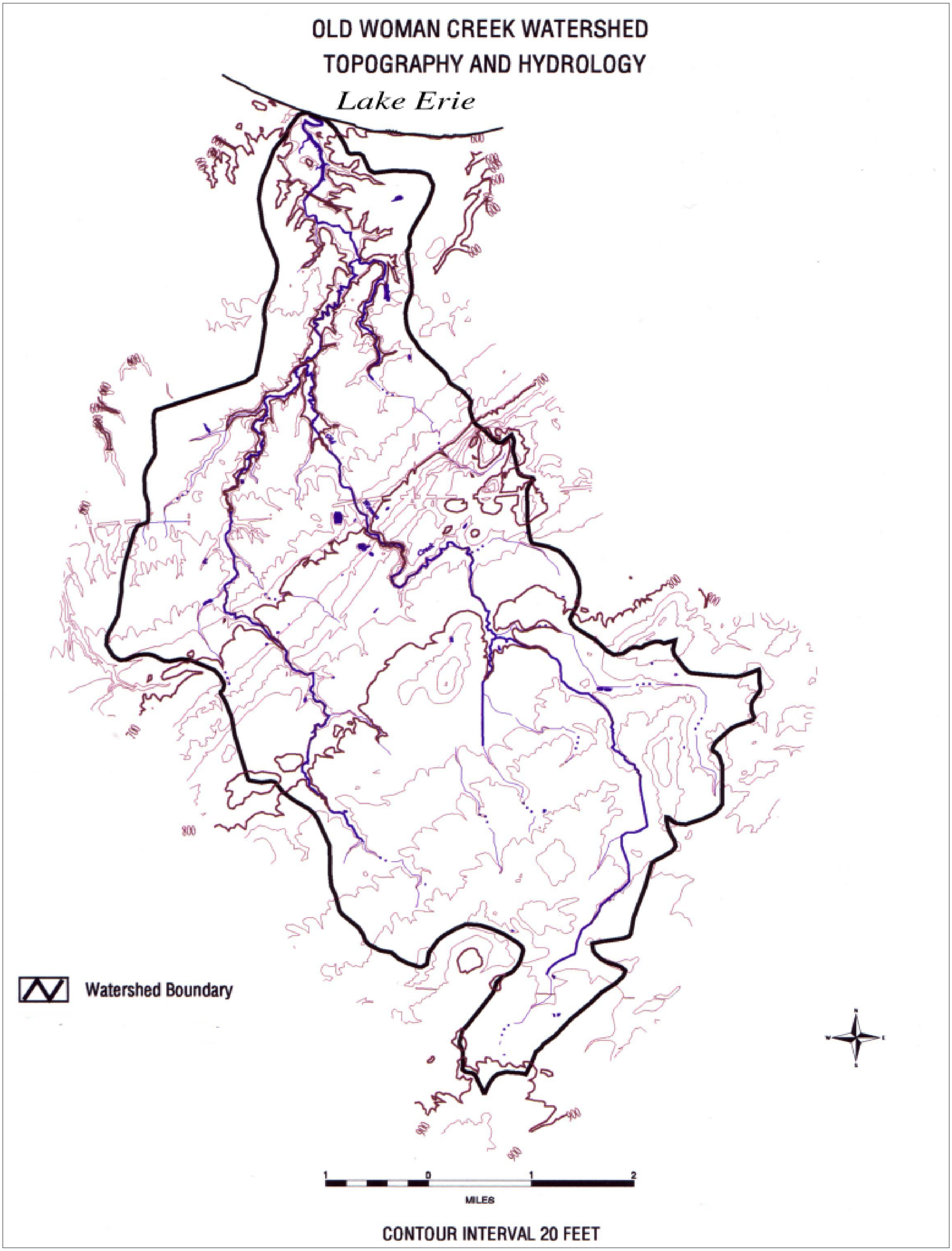


Figure 5.16. Surface drainage pattern of Old Woman Creek watershed.

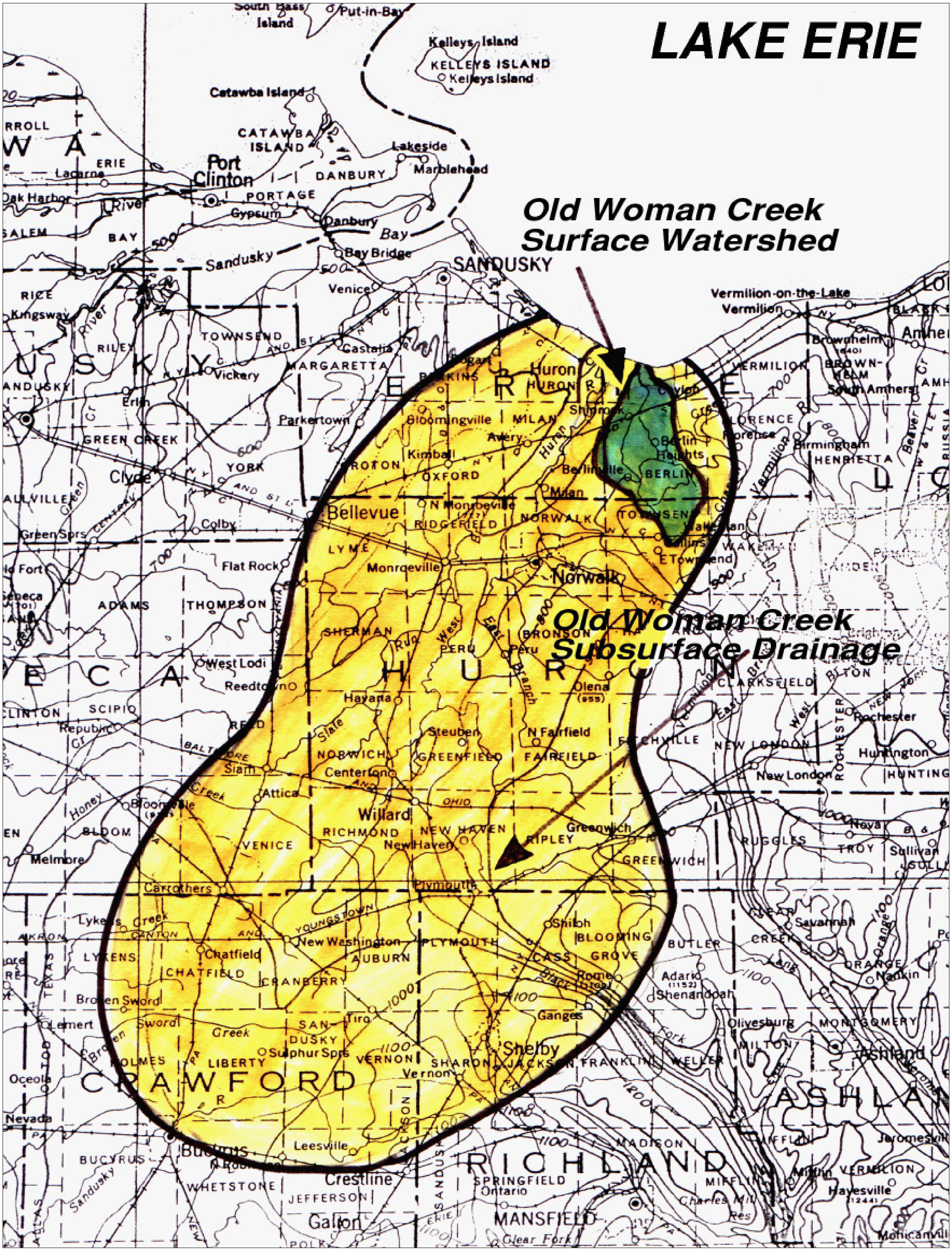


Figure 5.17. Subsurface drainage area for Old Woman Creek estuary.

GROUNDWATER

The geological formations beneath the surface of the Earth play an important role in the occurrence and development of groundwater. When rainwater strikes the ground, a portion flows across the surface of the land as "runoff" into streams and drains. The remainder seeps downward into the ground where it is temporarily stored. Water is contained in numerous openings, pore spaces, cracks, crevices between rocks, joints, bedding planes, fractures, or voids in the rock. These openings are usually interconnected, thereby permitting the movement of water from one opening to another. The quantity of groundwater in the watershed depends upon the size and number of these openings. The shape and the degree to which these openings are interconnected governs the amount of water available to wells. For this reason, wide variations in groundwater conditions are found because the geology differs in various locations in the watershed (Figure 5.18).

The amount of annual rainfall and temperature are the major climatic factors affecting the groundwater supply in any particular area. Recharge to aquifers is supplied directly or indirectly by precipitation, depending on the season of occurrence, its intensity, and whether it occurs as rain or snow. In the spring as the growing season starts, melted snow and rain usually result in large additions to the groundwater supply. However, layers of ice, or frost on the ground, can delay infiltration when thawing occurs. Under these conditions, water from snowmelt and early spring rains may be lost by quick surface runoff. In the fall of the year after the end of the growing season, when evaporation losses are reduced by cooler weather, substantial rises in groundwater levels usually occur from rainfall.

Groundwater Hydrology

Within Old Woman Creek watershed groundwater is present in pore spaces in sandstone, in joints and fractures in shale, and between the grains of sand and gravel. Groundwater supplies wells, keeps streams flowing during dry periods, and saturates certain soils to sustain wetland vegetation. Groundwater yields in the watershed (Figure 5.18) can be classified into three zones (Stein 1962a,b). In the vicinity of the estuary, from the lakeshore south to Ohio Route 2, yields are relatively high at 25 to 100 gallons per minute (about 100 to 400 l/min). Groundwater is developed from several lenses of sand and gravel interbedded in thick layers of clay. The preglacial valley that trends to the southwest under the Reserve has been penetrated by water wells drilled to 38 m without reaching bedrock. Such wells generally stop in sand and gravel lenses which are good producers of groundwater. From Ohio Route 2 south to Berlin Heights and then southwest to the Huron County line, groundwater yields are poor at less than 5 gallons per minute (<20 l/min). Surface material in this zone is glacial drift, composed predominantly of clay, underlain by shale and some thin sandstone. Wells developed in the upper weathered portion of the bedrock yield an average of 3 gallons per minute. The remainder of Old Woman Creek watershed south of Berlin Heights and into Townsend Township of Huron County has moderate groundwater yields ranging from 5 to 25 gallons per minute (about 20 to 100 l/min). In this zone sandstone and shale bedrock is covered with an average of 12 m of glacial drift. Sandstone typically yields 5 to 20 gallons per minute (about 20 to 75 l/min) at depths up to 40 m.

Groundwater Quality

Walker (1986) and Hartzell (1986) reported the quality of groundwater in Erie and Huron Counties from test wells in the vicinity of Old Woman Creek watershed. Wells Erie-C and Huron-B are located in the buried preglacial valley that trends to the southwest from the present mouth of Old Woman Creek, while wells Erie-D and -E are in sandstone and shale terrain, respectively (Table 5.19). Wells developed in the Ohio Shale have the lowest yield and the poorest quality, while sand and gravel lenses in the buried valley have the best yield, but not necessarily the best quality.

The Ohio Department of Natural Resources, Division of Water has determined that the lower valley of Old Woman Creek (surrounding the estuary) has the highest potential for groundwater pollution while, the higher ground portions of the watershed (remote from the estuary) have the lowest potential (Figure 5.19). This situation appears to be related to pollutants from agricultural sources that have a greater potential for infiltrating the groundwater in the quiescent estuary as compared to the more rapidly flowing upstream surface waters.

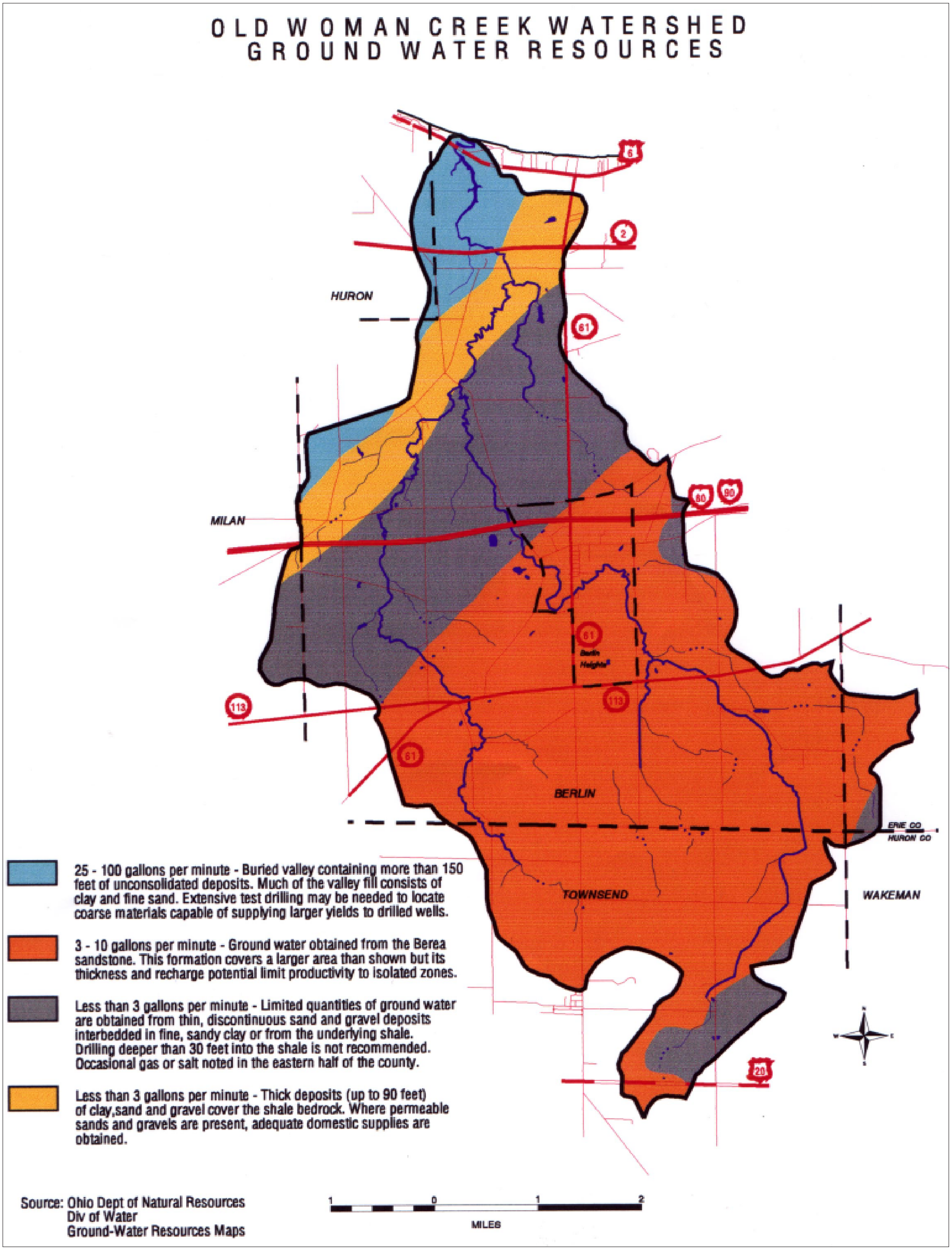


Figure 5.18. Groundwater resources of Old Woman Creek watershed.

TABLE 5.19. GROUNDWATER QUALITY OF THE WATERSHED

Parameter	Erie-C	Erie-D	Erie-E	Huron-B
Location (Twp)	Milan	Berlin	Florence	Willard
Depth	45.0	30.0	21.0	12.0
Aquifer	sand&gravel	sandstone	shale	sand&gravel
Iron (Fe mg/l)	1.3	0.9	1.1	0.8
Calcium (Ca mg/l)	82.0	86.0	8.2	78.0
Sodium (Na mg/l)	30.0	21.0	479.0	17.0
Chloride (Cl mg/l)	0.6	10.0	134.0	27.0
Fluoride (Fl mg/l)	0.4	0.2	0.8	0.2
Sulfate (SO_4 mg/l)	68.0	72.0	188.0	134.0
Hydrogen sulfide (H_2S)	—	—	trace	—
Dissolved solids (mg/l)	—	328.0	1230.0	—
Hardness ($CaCO_3$ mg/l)	282.0	301.0	32.0	—
pH	7.5	6.8	8.0	7.9
Yield (gpm)	250	5	1	490

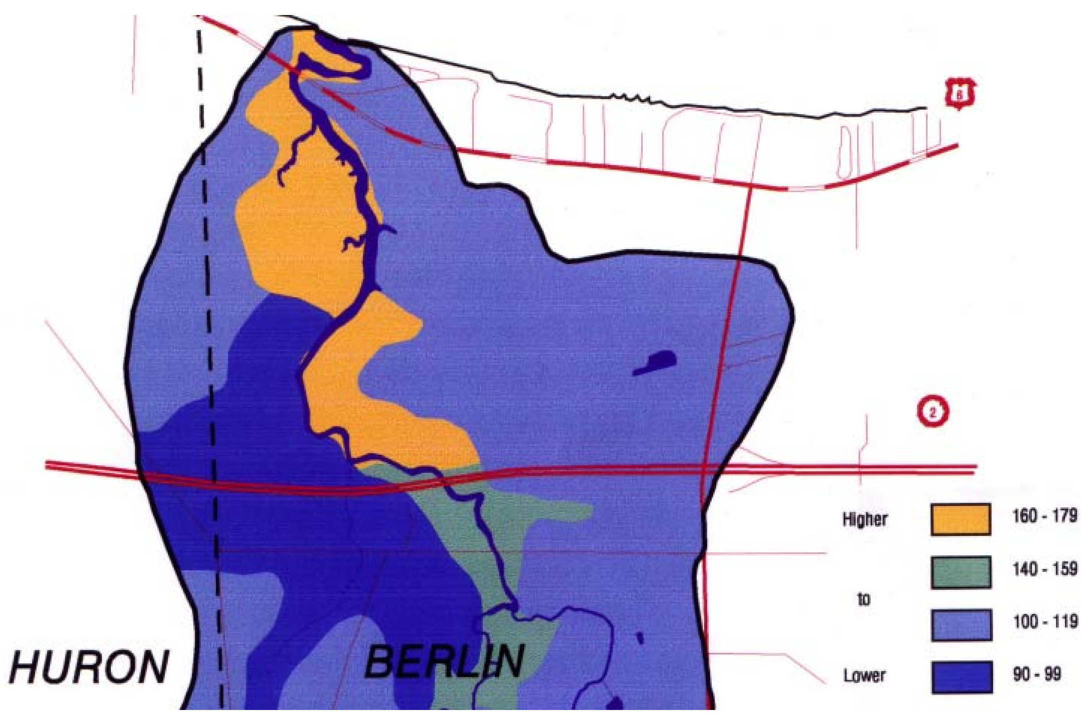


Figure 5.19. Groundwater pollution potential of the lower Old Woman Creek watershed (ODNR).

*Shagbark hickory (*Carya ovata*) on a bluff overlooking Old Woman Creek estuary (Charles E. Herdendorf).*

Chapter 6. Biology

Non-Vascular Plants

The non-vascular plants of the Old Woman Creek estuary and watershed include the algal flora and the lower plants. For the purposes of the Site Profile, "algal flora" is considered as those chlorophyll-bearing, aquatic organisms that lack vascular systems, true tissues, and root, stem, and leaf organs (Gray 1970) and "lower plants" include the fungi, lichens, mosses, horsetails, and ferns—those aquatic and terrestrial plant-like organisms with less complex vegetative and reproductive morphology than the gymnosperms (conifers) and angiosperms (flowering plants). In this profile, the grouping of species into divisions, classes, orders, and families follows the classification system presented in *Synopsis and Classification of Living Organisms* (Parker 1982), except where noted.

TABLE 6.1. CLASSIFICATION OF ALGAL FLORA AND LOWER PLANTS

Kingdom Monera	
	Cyanobacteria (blue-green algae)
Kingdom Protista	
	Rhodophytes (red algae)
	Chrysophytes (golden & yellow-green algae)
	Pyrrhophytes (fire algae)
	Cryptophytes (crytomonads)
	Euglenophytes (euglenoids)
	Chlorophytes (green algae)
Kingdom Fungi	
	Myxomycetes (slime molds)
	Phycomycetes (algal fungi & water molds)
	Ascomysetes (yeasts, molds, & cup fungi)
	Basidiomycetes (mushrooms, smuts, & rusts)
	Deuteromycetes (imperfect fungi)
	Mycophycohytes (lichens)
Kingdom Plantae	
	Bryophytes (mosses & liverworts)
	Lycopodiophytes (clubmosses)
	Equisetophytes (horsetails & scouring rushes)
	Filicophytes (ferns)

The algal flora and lower plants found in the vicinity of the Research Reserve embrace four of the five kingdoms of living organisms (Margulis and Schwartz 1988). As defined by Round (1969), this grouping includes the major divisions (with typical examples) listed in Table 6.1.

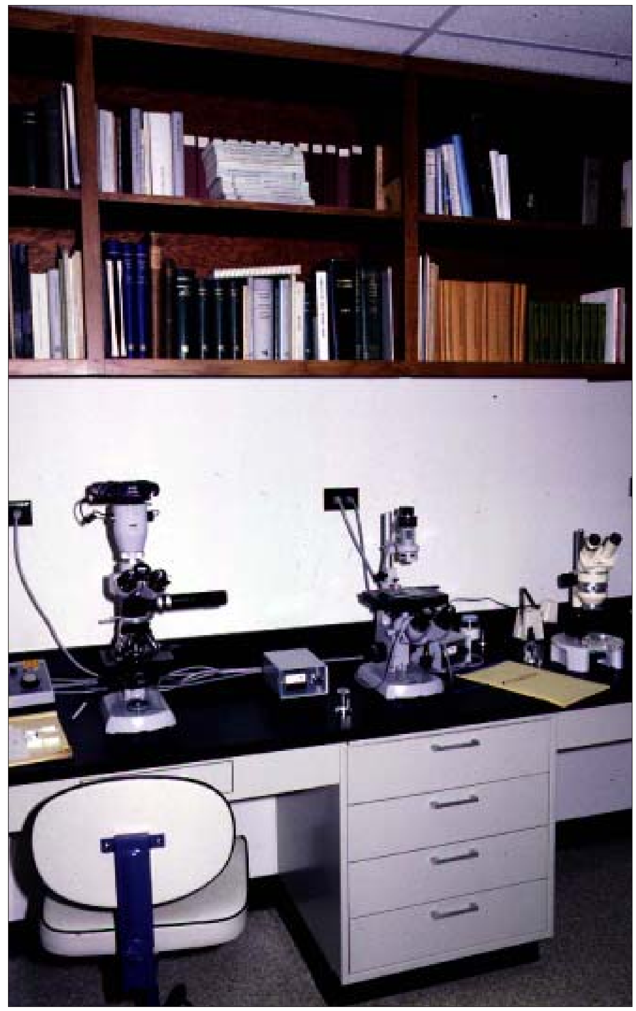


Figure 6.1. Phycology laboratory at the Ohio Center for Coastal Wetlands Study, Old Woman Creek SNP & NERR (David M. Klarer).

Research within the Old Woman Creek estuary and watershed has documented 682 algal species (Figure 6.1) and 648 lower plant species (Appendix A). A detailed treatment of these groups is contained in Old Woman Creek SNP & NERR Technical Report No. 13: *Catalogue of the Algal Flora and Lower Plants of Old Woman Creek Estuary, Watershed, and Adjacent Waters of Lake Erie* (Klarer et al. 2001).

ALGAL FLORA

The primary features used to classify algae into seven divisions include: (1) nuclear type, (2) pigmentation, (3) cell wall composition, and (4) locomotory organs (Bold and Wynne 1985). These characteristics are detailed in Table 6.2.

DIVISION CYANOPHYTA (BLUE-GREEN ALGAE)

Blue-greens, sometimes called cyanobacteria, are the most primitive photosynthetic organisms in the estuary. Like the true bacteria, they have a prokaryotic cell structure—characterized by the lack of a nuclear membrane and distinct chloroplasts (plastids containing chlorophyll). The cell walls are composed of mucopeptide, similar to that of bacteria. Blue-greens also lack flagella and the only motility results from gliding trichomes – filaments without the investing sheath (Prescott 1962). They occur in unicellular, filamentous, and colonial forms, and most are enclosed in a gelatinous sheath. Blue-greens also occur in attached benthic forms. Blue-green algae contain specialized cells, known as heterocysts (sites of nitrogen fixation) a feature unique to this group. Photosynthetic products are glycogen and glycoproteins rather than starch. There is no direct evidence of sexual reproduction such as conjugation as observed in some bacteria (Dawes 1981); vegetative reproduction by fragmentation is most common and can be more rapid than in other phytoplankton groups (Pentecost 1984).

TABLE 6.2. PRIMARY FEATURES IN THE CLASSIFICATION OF ALGAL DIVISIONS

Name & Typical Color	Nucleus	Pigment	Cell Wall	Locomotion
Cyanophyta (blue-green)	prokaryotic	chlorophyll *a* phycocyanin phycoerythrin	mucopeptide	some float & glide
Rhodophyta (red)	eukaryotic	chlorophyll *a,d* carotenoids phycoerythrin	cellulose	attached
Chrysophyta				
chrysophytes (golden-brown)	eukaryotic	chlorophyll *a,c* carotenoids xanthophylls	pectin	few flagellated
xanthophytes (yellow-green)	eukaryotic	chlorophyll *a,c* carotenoids xanthophylls	pectin	most flagellated
diatoms (golden)	eukaryotic	chlorophyll *a,c* carotenoids xanthophylls	silica	sessile; some float
Pyrrhophyta				
dinoflagellates (red-brown)	eukaryotic	chlorophyll *a,c* xanthophylls	cellulose; may be in armored plates	all flagellated
Cryptophyta (various)	eukaryotic	chlorophyll *a,c*	absent carotenoids phycoerythrin	flagellated
Euglenophyta (green)	eukaryotic	chlorophyll *a,b* xanthophylls	absent	flagellated
Chlorophyta (grass green)	eukaryotic	chlorophyll *a,b* carotenoids xanthophylls	cellulose	some flagellated

Most of the blue-greens identified in Old Woman Creek estuary are planktonic and are either spherical-shaped members of the family Chroococcacea (e.g. *Microcystis* and *Coelosphaerium*) or unbranched, filamentous forms (e.g. *Anabaena* and *Oscillatoria*) in several families. Representative species from Old Woman Creek and its estuary are: *Aphanocapsa delicatissima*, *Chroococcus dispersus*, *Gomphosphaeria lacustris*, *Anabaena spiroides*, *Oscillatoria agardhii*, and *Oscillatoria limosa* (Figures 6.2 and 6.3).

*Figure 6.2. Spherical blue-green alga (*Chroococcus*) from Old Woman Creek estuary (David M. Klarer).*

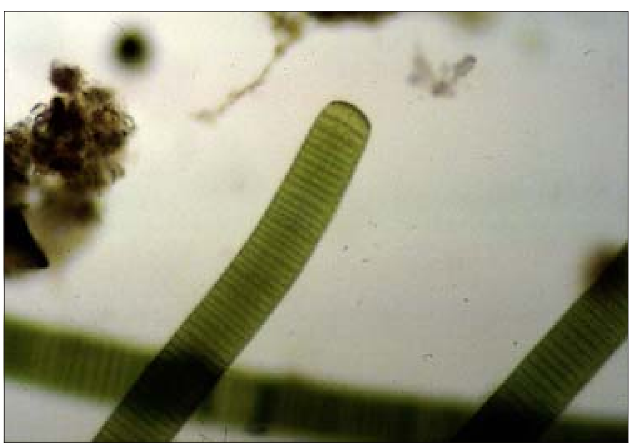


*Figure 6.3. Filamentous blue-green alga (*Oscillatoria*) from Old Woman Creek estuary (David M. Klarer).*

DIVISION RHODOPHYTA (RED ALGAE)

Red algae are sparsely represented in freshwater, including Old Woman Creek estuary where only filamentous benthic forms are present. No planktonic red algae occur in Lake Erie. The attached filaments colonize rocks and other hard substrates just below the splash zone. Because these algae contain red phycoerythrin and blue phycocyanin that mask their chlorophyll, they generally appear reddish in color. The cell wall is composed of cellulose. There is a complete lack of any flagellate stages in this group. Red algae stores polysaccharides such as floridian starch, agar, and carrageenan (Lerman 1986). Reproduction is by sexual and asexual means for the species that have invaded Lake Erie. A distinguishing characteristic of red algae is the cystocarp, a spore-forming structure that follows fertilization and the meiotic division of the zygote (Taft and Taft 1971).

The only representative of the Division Rhodophyta in the Old Woman Creek area is *Bangia atropurpurea*, which grows attached to some shore protection structures in Lake Erie off of the mouth of the creek. The attached filaments colonize the rocks and other hard substrates just below the splash zone. The simple, unbranched filaments are brownish purple in color and appear in late spring to early summer, but disappear by mid-summer.

The other major marine algal group, Phaeophyta (brown algae), is almost exclusively oceanic and benthic. There are no freshwater species that have been reported in the flora of Lake Erie or Old Woman Creek estuary.

DIVISION CHRYSOPHYTA (GOLDEN & YELLOW-GREEN ALGAE)

This division of algae consists of three important classes: Chrysophyceae (golden-brown algae), Xanthophyceae (yellow-green algae), and Bacillariophyceae (diatoms).

Class Chrysophyceae (golden-brown algae)

Chrysophytes contain chromatophores that often produce a golden-brown color because of the high content of carotenoid and xanthophyll pigments. Most chrysophytes are unicellular and most cells are unflagellated. Many species lack a cell wall; others are covered with calcareous or siliceous scales.

Vegetative reproduction by longitudinal cell division is the most common type (Wetzel 2001). Representative benthic and planktonic species from Old Woman Creek and its estuary are: *Chrysococcus* spp., *Kephryion* spp., *Pseudokephyrion* spp., *Mallomonas acaroids*, and various *Dinobyron* species including *D. bavaricum* and *D. divergens*.

Class Xanthophyceae (yellow-green algae)

Yellow-green algae are unicellular, colonial, or filamentous in form and are characterized by noticeable amounts of carotinoid pigments in comparison to chlorophyll that results in their distinct coloration. Most cells are motile, actuated by two flagella, one of which is considerably longer than the other. The cell wall, when present, contains a large amount of pectin and some species are silicified. Reproduction is largely asexual by fission. Xanthophytes are often associated with substrates, many being epiphytic on macrophytes (Wetzel 2001), but a few are planktonic. Although this group of algae is not well represented in Old Woman Creek and its estuary, *Ophiocytium capitatum* var. *longispina* is often observed in the plankton of the estuary (Figure 6.4).

*Figure 6.4. Yellow-green alga (*Ophiocytium capitatum *var.* longispina*) from Old Woman Creek estuary (David M. Klarer).*

Class Bacillariophyceae (diatoms)

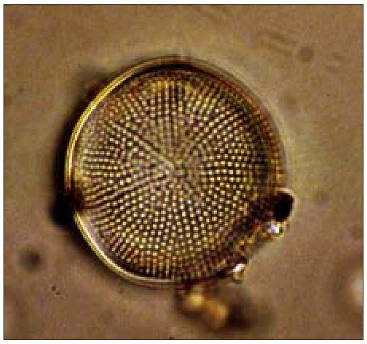
The primary characteristic of diatoms is an often ornate, siliceous cell wall (frustule). This wall consists of two lid-like halves, the epitheca (upper valve) that fits into the hypotheca (lower valve), which are connected by a girdle of cell wall material (Wetzel 2001). Both unicellular and colonial growth forms are common among the diatoms. Diatoms contain both chlorophyll *a* and *c*, carotene, and some xanthophylls. They store energy as fat and oil in large globules. This group is divided into centric diatoms (order Centrales), which have radial symmetry, and pennate diatoms (order Pennales), which are elongated with bilateral symmetry (Figure 6.5). Vegetative reproduction by cell division is the most common mode and usually takes place at night. Sexual reproduction takes place periodically when cells reach a critical minimum size through repeated asexual cell division.

Diatoms compose one of the most important algal groups in the estuary and the most important algal group in Lake Erie's nearshore waters from the standpoint of carbon fixed and oxygen produced. Over 300 species of diatoms have been identified from these habitats. Although the majority of species are sessile and associated with littoral vegetation or bottom sediments, many are important in the phytoplankton. Within Old Woman Creek, the attached species of *Gomphonema* spp., *Navicula* spp., and *Nitzschia* spp. are most common. The most important benthic diatoms in the estuary are also species of *Navicula* spp. and *Nitzschia* spp. Within the plankton in the estuary, *Aulacosieira alpigena*, smaller species of *Cyclotella* including *C. atomus* and *C. meneghiniana*, and a variety of smaller *Nitzschia* spp. are most common.

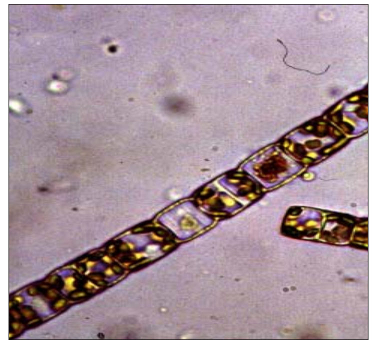
DIVISION PYRRHOPHYTA (FIRE ALGAE)

Class Dinophyceae (dinoflagellates)

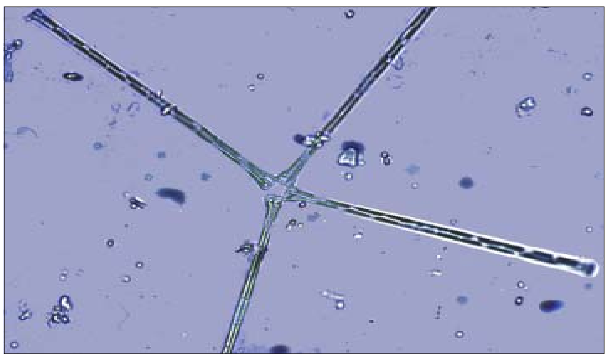
The common characteristics of this division are the preponderance of brownish pigment such as peridinin, starch and oil food reserves, and cellulose in the cell walls (Taft and Taft 1971). Dinoflagellates are unicellular flagellated algae, many of which are bizarre in shape and structure and many of which are motile. Most species have developed a conspicuous cell wall that is sculptured and bears large spines and elaborate, articulated plates. The body structure includes a transverse groove or "girdle" that encircles



Actinocyclus normanii (centric)



Stephanodiscus binderanus (centric)



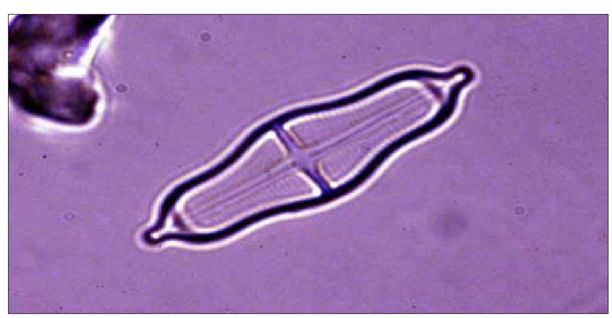
Asterionella formosa (pennate)

Gomphonema olivaceum (pennate)

Gomphonema sp. (pennate)

Nitzschia hungarica (pennate)

Pinnularia obscura (pennate)



Stauroneis smithii (pennate)

Figure 6.5. Centric and pennate diatoms from Old Woman Creek estuary (David M. Klarer).

the cell. Dinoflagellates differ from other bi-flagellated algae in having one of the two flagella circumscribing the body in a transverse groove while the other extends from the girdle posteriorly through a narrower groove. In most species the body is armored with thick cellulose plates ranging in color from reddish-brown to yellow, which form a case or theca. The shape and number of these plates are an important taxonomic character for species identification. The upper part of the armored cell is referred to as the epitheca and the lower part is the hypotheca. Reproduction in the motile forms is usually by vegetative cell division.

A common Lake Erie planktonic dinoflagellate is the genus *Ceratium*, which has a shape that often resembles the Eiffel Tower (Figure 6.6). The genus *Gymnodinium*, which at times reaches bloom proportions in the estuary, has green chromatophores, but lacks a distinct protective cellulose theca. Except for a brief period during 1981 when *Gymnodinium aeruginosum* reached bloom proportions, Dinoflagellates have not been a major component in the algae of Old Woman Creek estuary. Other species infrequently observed in the estuary are *Ceratium hirundinella* and *Perdiniopsis quadridens*.

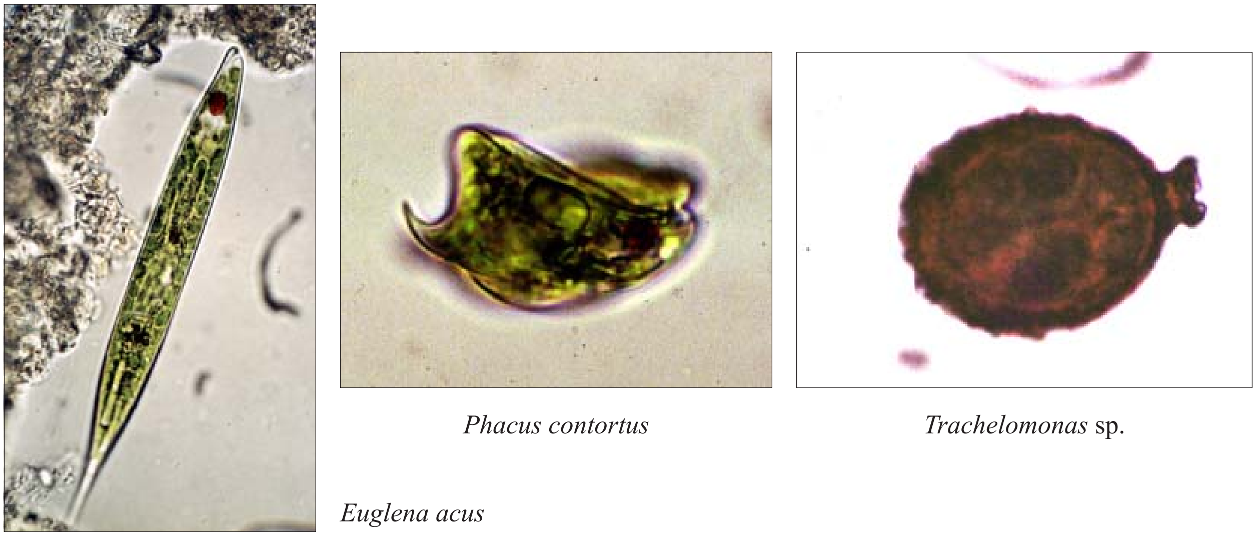
*Figure 6.6. Dinoflagellate (*Ceratium*) from Old Woman Creek estuary (David M. Klarer).*

Figure 6.7. Cryptomonas *sp. (cryptomonad) a common genus found in Old Woman Creek estuary (Donald Ott).*

DIVISION CRYPTOPHYTA (CRYPTOMONADS)

Cryptomonads have ovoid to slipper-shaped cells that are rather flattened in appearance. These small, unicellular algae are motile by virtue of two anterior flagella. They are naked, in that they lack true cell walls, but possess distinct reservoir pockets and chloroplasts which contain pigments ranging from olive brown to blue to red. The one or two chromatophores in the cell contain a variety of pigments that can absorb a wide spectrum of light. Although small, these algae can have dense populations even during cold periods of the year under low light conditions (Wetzel 2001). Cryptomonads have a long longitudinal furrow and two anterior flagella. The food reserve is starch and oil.

Cryptomonads comprise a common planktonic group in the estuary and Lake Erie. They can be particularly abundant in the winter months under low light conditions. Common representatives include several species of *Crytomonas* and *Rhodomonas* (Figure 6.7). Cryptomonads are an important group in the estuary as *Cryptomonas erosa*, *C. ovata*, and *Rhodomonas minuta* var. *nannoplanctonica*, are often present in large numbers through the spring and summer.



Phacus contortus *Trachelomonas* sp.

Euglena acus

Figure 6.8. Euglenoids from Old Woman Creek estuary (David M. Klarer).

DIVISION EUGLENOPHYTA (EUGLENOIDS)

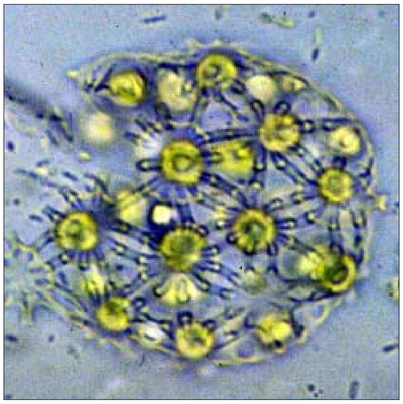
Organisms known as "euglenoids" constitute a controversial group in terms of the traditional plant verses animal debate. Most euglenoids are chlorophyll-bearing (chlorophytes), protozoa-like organisms of the Protista, and as such the chlorophytes can be considered members of the algae, division Euglenophyta (Taft and Taft 1971). Euglenoids in the order Peranemida are colorless and obtain their nutrition by absorbing dissolved food through the cell membrane (saprobic) or by the ingestion of organic material as animals must do (holozoic). Because they exhibit a distinct gullet in contrast to the indistinct gullet of the pigmented euglenoids, they are considered invertebrate protozoans and are not here included as a component of the algal flora. Appendix C and Old Woman Creek SNP & NERR Technical Report No. 12: *Catalogue of Invertebrate Fauna of Old Woman Creek Estuary, Watershed, and Adjacent Waters of Lake Erie* (Herdendorf et al. 2001d) contain information on protozoan euglenoids reported for the Research Reserve.

Euglenoid algae are unicellular flagellates that typically have grassy-green chloroplasts and a reddish stigma (eyespot). Haematochrome is often present along with chlorophyll and may give a blood-red coloration to the cell (Taft and Taft 1971). Almost all euglenoids are unicellular and free-swimming, but some are attached by stalks to various invertebrates (epizooic). They lack a distinct cell wall, but some possess a smooth outer membrane while others may have an ornamented lorica. Euglenoids have one to three flagella that arise from a canal in the cell membrane. Certain species possess a prominent orange-red eyespot which receives light stimuli. Such species have been found to be positively phototactic to low light intensity and negatively phototactic with respect to bright light and darkness (Bold and Wynne 1985). Body shapes are cylindrical, pyriform, fusiform, or ovoid. They store carbohydrates as granules in specialized reservoirs. Reproduction is asexual by longitudinal division of a motile cell.

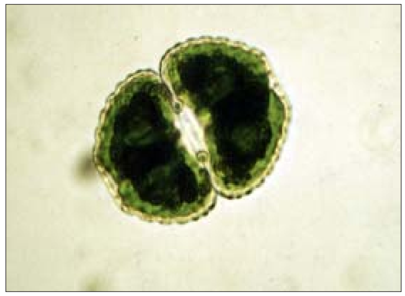
Although few euglenoid species are truly benthic, most are planktonic in the estuary. Members of the genus *Trachelomonas* are housed in a self-secreted lorica which varies in shape depending on the species and environmental conditions. Representative species from Old Woman Creek and its estuary are: *Euglena acus*, *E. oxyuris*, *Phacus caudatus*, *Strombomonas longicauda*, *Trachelomonas volvocina*, *T. oblonga*, and *Lepocinclis ovum* (Figure 6.8).

DIVISION CHLOROPHYTA (GREEN ALGAE)

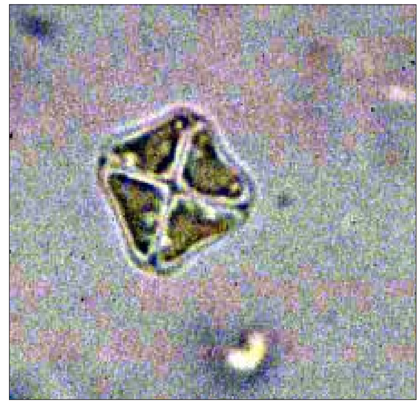
Green algae are characterized by grass-green chloroplasts (pigment packets), one to many in each cell, and a firm cell wall composed of an inner layer cellulose and an outer layer of pectinaceous compounds (Figure 6.9). Green algae is the major phytoplankton



Coelastrum cambricum



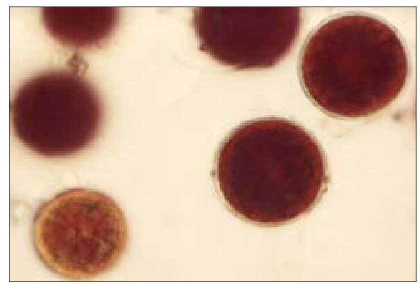
Cosmarium formosulum



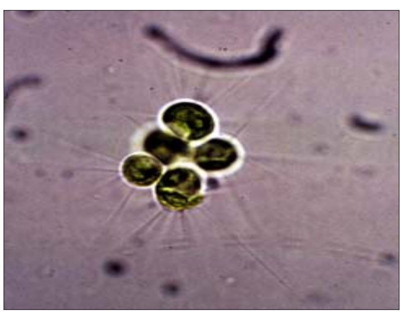
Crucigenia tetrapedia

Crucigeniella rectangularis

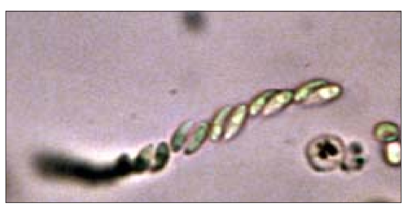
Dictyosphaerium puchellum



Haematococcus pluvialis

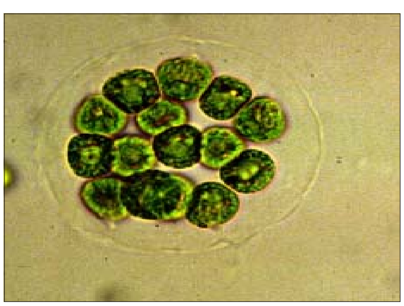


Micractinium pusillum

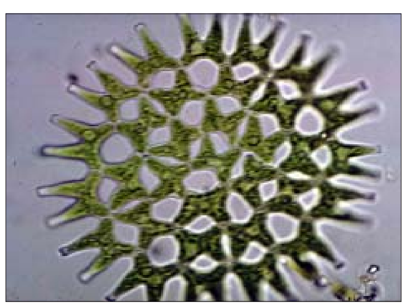


Neodesmus danubialis

Ooystis sp.



Pandorina sp.



Pediastrum boryanum

Scenedesmus opoliensis

Figure 6.9. Representative planktonic green algae from Old Woman Creek estuary (David M. Klarer).

group to contain chlorophyll *b* (a constituent of vascular plants) and is thought to be a precursor of higher plants. Some species have a stigma or red eyespot that is thought to be the site of light perception (Bold and Wynne 1985). Starch is the primary food product which is stored in structures known as pyrenoids.The body plan of greens shows a great range of cellular organization, including unicellular, colonial, filamentous (simple or branched), membranous (sheetlike), and tubular types. Green algae also occur as filamentous benthic forms, usually attached to hard substrates such as rocks or submerged logs. Green algae frequently have a unicellular stage of their life cycle which is flagellated and motile (Goldman and Horne 1983). This enables filamentous forms to colonize suitable, but discontinuous, substrates. Reproduction in green algae is asexual by vegetative division and cell division (particularly for colony enlargement), and sexual by the production of various styles of gametes.

Chlorophytes represent a large and diverse group of algae in the estuary and include both benthic and planktonic forms. Green algae are a major component of the phytoplankton and includes such common genera as *Ankistrodesmus*, *Chlamydomonas*, *Closterium*, *Scenedesmus*, and *Pediastrum* (Figure 6.9). Filamentous, benthic forms of green algae include *Cladophora* and *Ulothrix*. Representative species from Old Woman Creek and its estuary are: *Chlamydomonas globosa*, *Ankyra judayi*, *Pediastrum simplex* var. *simplex*, *Lagerheimia genevensis*, *Oocystis lacustris*, *Scenedesmus opoliensis*, *Cladophora glomerata*, and *Spirogyra* sp.

LOWER PLANTS

Although most groups of lower plants are active in carbon fixation and the building of more complex organic molecules through the process of photosynthesis, bacteria and fungi also perform the equally vital breakdown of organic matter. Without these recycling organisms, the land and waters of the Reserve would rapidly become choked with debris that could only be decomposed slowly by chemical processes. Many of the environmental processes that we think of as purely chemical are mediated by microorganisms, such as the formation of rust (iron oxidation) which can be facilitated by the bacteria *Leptothrix*—a common form in freshwater marshes. While bacteria tend to invade any organism as soon as it dies or is damaged, fungi are often secondary invaders because they are larger and slower growing (Round 1969). Saprophytic fungi, those growing on dead material, are thus the most numerous. Fundamentally, fungi are plant-like organisms that lack chlorophyll, cilia, or flagella (except some chytrids and oomycetes) and that form spores. Many construct a complex interweaving mass of fungal hyphae (filamentous threads that make up the body of a fungus) in upland habitats, while unicellular species occur in the sediments of the estuary and surrounding soil, releasing fungal spores or fragments into the water and air.

DIVISION MYXOMYCOTA (MUCUS MOLDS)

Class Myxomycetes (true slime molds)

Slime molds are "animal–like plants" found in freshwater, in damp soil, and on rotting vegetation, particularly in woodlands on fallen logs. In the course of their life cycle, independently feeding amoeboid forms aggregate into a slimy mass or wet scum (plasmodium) that eventually dries and transforms itself into a spore-forming reproductive body. Once released, the spores are dispersed by air currents. Typically the plasmodia are pigmented orange or yellow, but none photosynthesize. They feed by engulfing decaying vegetation. As the mass dries the plasmodial protoplasm becomes concentrated into a mound, from which stalked fruit (sporangia) grow. Some 50 species of Myxomycetes have been reported in the region surrounding the Reserve.

DIVISION PHYCOMYCOTA (ALGAL FUNGI & WATER MOLDS)

Members of this division of fungi are believed to be derived from algal progenitors which had lost their chlorophyll. As a result, phycomycetes have assumed a parasitic or saprophytic mode of life. Most species have nonseptate mycelium, in that they do not have cross walls in the mass of hyphae constituting the body of the fungus. This division contains the water molds which are frequently parasitic on algae or inhabit organic sediments. Over 40 species of both parasitic and saprophytic water molds have been reported in the Lake Erie islands to the west of the Reserve, while several species of *Achlya* have been reported in Old Woman Creek.

Class Chytridiomycetes (chytrids or cooking pot fungi)

These tiny fungi are the only ones which possess motile cells with a single posterior flagellum. Chytrids have a simple, sac-like thallus (undifferentiated body). Many species are aquatic and parasitize algae to such an extent that they can alter the balance of populations (Round 1969). Others are saprophytic on plants and animals in water and soil. Like other fungi, they feed and grow by extending threadlike hyphae (sometimes called rhizoids) into living hosts or dead organic debris, where they secrete digestive enzymes and absorb the resulting nutrients.

Class Oomycetes (egg fungi)

Oomycetes include fungi known as water molds, white rusts, and downy mildews. They also feed by extending hyphae into their hosts tissue and appear most commonly as a gray fuzz on dead animals. *Saprolegnia* causes diseases in fish and fish eggs and may do significant damage in a fish hatchery. Members of this genus invade the skin of fish, consume scales and flesh, and finally kill the fish. Oomycetes produce zoospores that swim by means of two flagella (undulipodia) of unequal length. After transformation, zoospores germinate and grow a new thallus, the cell walls of which are composed of cellulose.

Class Zygomycetes (pair fungi)

This class of fungi lacks cross walls (septa) and reproduces by means of spores and by conjunction (transmission of genetic material from a donor to a recipient cell). No flagellated cells have been found in this class. Many of them live on decaying vegetation. Representatives of two orders have been reported in the region surrounding the Reserve. Members of the order Mucorales are mostly saprobic, in that they excrete extracellular digestive enzymes and adsorb dead organic matter, whereas those in the order Entomophthorales are parasitic on animals, mainly insects.

DIVISION ASCOMYCOTA (ASCOMYCETES OR BLADDER FUNGI)

This division contains many familiar forms of fungi, such as yeast, fruit molds, morels (Figure 6.10), and truffles, as well as most of the fungal partners in lichens and other diverse parasitic and pathogenic forms. Members are known by one distinguishing feature, the ascu—from which the name of this division is derived—a saclike structure containing the spores (ascospores). Some of the spore-producing fruiting bodies are large and edible, such as the morel or sponge mushroom, *Morchella*.

*Figure 6.10. The common morel (*Morchella esculenta*) is found on wooded soils of the watershed (from Keizer 1997).*

Class Hemiascomycetes (yeasts)

This class includes many yeasts and other simple asconomycetes, such as fungi which cause peach leaf curl (*Taphrina deformans*) and plum pockets (*Taphrina communis*). The asci of this group is not enclosed in an ascocarp (a spherical or cup-shaped fruiting body). Many species are parasitic on ferns and higher plants, causing spots and galls on leaves, stems, and fruit.

Class Loculoascomycetes (scab molds)

This class contains many species which are parasitic on economically important food plants. Some attack the leaves of many plants while others cause apple and pear scab. Members of this class have a characteristic bitunicate asci—the inner wall of the spore sac is elastic and expands greatly beyond the outer wall when spores are released.

Class Plectomycetes (fruit molds)

Aspergillus and *Penicillum* are well known genera in this class. These fungi form green and blue colonies on fruit and produce organic acids that attack natural fibers. The fruiting bodies (ascocarps) are formed by a loose interwoven mass of hyphae, while the asci are usually unitunicate—the inner and outer ascus wall are more or less ridged and do not separate when spores are ejected. The spores are dispersed by air currents.

Class Pyrenomycetes (flask fungi)

This class contains the powdery mildews (order Erysiphales) and several orders of flask-shaped fungi. The "powdery" nature of the mildew is the result of chains of spores (conidia) budding off the spore sacs (conidiophores) at the tips of the hyphae. These fungi are mostly superficial, creating a coating of mycelium on stems, leaves, buds, and fruits of the host plants. The flask fungi, usually dark or brightly colored, often infest grasses and grains, producing a hardened hyphal mass (sclerotium) that resembles the grain in shape.

Class Discomycretes (disc fungi)

This class includes cup fungi, earth tongues, and rots. Brown rot of stone and pome fruits (e.g. peaches and apples) is caused by members of the genus *Sclerotinia*. This fungus spreads rapidly by means of oval conidia budding off in chains. As the growing season progresses, the hyphae which have spread throughout the fruits causes them to shrivel and mummify—they can often be seen attached to the fruit trees in winter. Those which fall to the ground and become buried will, in later years, grow long-stalked fruiting bodies (apothecia) of cup fungus from the mummified fruits (Round 1969).

DIVISION BASIDIOMYCOTA (BASIDIOMYCETES OR SMALL BASE FUNGI)

Basidomycetes are the most advanced division of fungi and can be distinguished from all others by the basidium—a microscopic clublike reproductive structure (spore producer) from which their name is derived. This division contains all of the woody fungi and nearly all of the large fleshy forms, including all but a few of the edible and poisonous mushrooms. Most basidomycetes go through three stages of development, involving the production of basidiospores which upon germination give rise to septate (cross-walled) mycelia with uninucleated cell. When two compatible hyphae from mycelia meet, nuclei pass from one to another and a binucleated mycelium is formed, from which the plant body (thallus) is produced. With forest trees and shrubs, certain basidomycetes form symbiotic associations called mycorrhizae. Mycorrhizal fungi are important mediators in the transfer of phosphorous and nitrogen to the host plants.

Class Teliomycetes (rust & smut fungi)

Two important groups of plant parasites—smuts and rusts—form this class. The smuts form sootlike masses (teliospores) in the ovaries of grasses, in the anthers of the pink family (Caryophyllacea), and on the leaves of the buckwheat family (Polygonaceae). The parasitic mycelium tends to concentrate in the meristematic regions of the plant (sites of active cell division) without causing much damage to vegetative growth. The rusts are much more complex and are mostly obligate parasites producing colored (often red) spore bodies (sori) which burst through the leaf or stem of the host. Some rusts have up to five stages in their complex life history. The most infamous of the rusts is *Puccinia graminis*, which causes black stem rust of wheat. According to the Erie County office of the Ohio Agricultural Extension Service, *P. graminis* occurs in the watershed, but has not been a major problem.

Class Phragmobasidiomycetes (jelly & waxy fungi)

The bodies (basidocarps) of these fungi are gelatinous to waxy. Many have brilliant yellow, orange, or reddish pigments. In the order Eutremellales, the basdia are borne in capsules extended above the surface of the gelatinous fruit body. *Tremella* (found regionally) forms a large, pigmented, foliose body that obtains nutrition saprophytically. Called trembling fungus, it looks like soft, clammy, yielding folds of jellylike material up to 10 cm high and wide that has a glistening appearance. Some species are edible.

Class Hymenomycetes (exposed hymenium fungi)

All of the species in this class have a fruiting body with an exposed fertile surface (hymenium), such as gills, lined with basidia. Most of the mushroom-like fungi are included in the large order Agaricales, within this class. Over 80 species in the order have been reported for the region surrounding the Reserve. In this group, the cap (pilus) bears flat "gills" radiating from the stalk. The development process begins underground as small button-like swellings appear on mycelial strands that gradually swell to form short stalks and hemispherical caps. Between the cap and the stalk a chamber appears where the gills form. Rapid expansion of the fruit body tears the connection between the cap's rim and the stalk leaving the torn tissue as a skirt-like annulus around the base of the base of the stalk. In the death cap, genus *Amanita*, a further layer of tissue covers the whole developing body (basidiocarp), but also eventually tears leaving a cup-like structure (volva) at the base of the stalk.

Class Gasteromycetes (stomach fungi)

Puff-balls are among the most common types of the Gasteromycetes and are found on the ground or on decaying wood in the vicinity of the Reserve; members of the genus *Lycoperdon* are typical of this group. The spores are formed in cavities which gradually enlarge producing basidia on their internal surfaces. At maturity the whole inside of the bulbous thallus is full of spores and the outer surface (peridium) becomes papery. Holes eventually appear, from which the spores are "puffed" out whenever the fruit body is disturbed. Other genera have more complex peridia which split into layers and expand as in the earth stars (*Geaster*).

DIVISION DEUTEROMYCOTA (DEUTEROMYCETES OR IMPERFECT FUNGI)

The imperfect fungi is an artificial division characterized by the absence of a sexual state, in which both Ascomycota-like mycelium and Basidiomycota-like mycelium are represented, but species can not be placed in either of these divisions because their sexual state is not known. Most of the fungi that are pathogenic for humans are deuteromycetes. They form asexual spores, often several varieties in the same species. Many of them have a yeast-like parasitic phase as well as a mycelial saprophytic phase. Two classes are recognized by Parker (1982): the Hypomycetes, a group in which the propagation unit (conidium) is not formed within an enclosed structure and the Coelomycetes, a group in which spore formation is initiated within a closed fruiting body.

DIVISION MYCOPHYCOPHYTA (LICHENS OR FUNGUS ALGAE)

Lichens constitute a special group of thallophytes (plant body not differentiated into roots, stems, and leaves), in that they are a symbiotic association of a fungus and an alga. The algal member is usually a blue-green or green alga and the associated fungus is most commonly an ascomycete, although a few lichens have a basidiomycete component. Lichens typically grow on tree trunks, rocks, and moist soil. They occur as dry crusty patched (crustose), leaflike scales (foliose), or erect, branched tuffs (fruticose), and their colors range from gray-green, yellow-orange, brown, and white to black. Like the Deuteromycetes, Margulis and Schwartz (1988) consider lichen to constitute a separate "form division" and that classification is used for the purposes of this Site Profile. Wolfe (1940) presented a grouping of lichen genera into orders and families in his pioneering work, *A Catalog of the Lichens of Ohio*. Virtually all records of lichens are from regional studies, as no study has been undertaken in the watershed since the inception of the Research Reserve.

The lichen partners are quite different from their free-living partners. The symbiots consist of algal cells embedded in the fungal mycelia, thus symbiosis is a crucial mechanism in the morphology, development, and evolution of lichens. Working together, the symbiots can synthesize organic acids and pigments that are lacking in individual algae and fungi growing alone. They are slow growing, as evidenced by studies of lichens on gravestone, indicating a growth of only a few millimeters in a century. The dotted twig lichen, *Ramalina farinacea*, which has been reported for Erie County, is listed as an Ohio endangered plant species.

LOWER VASCULAR PLANTS

DIVISION BRYOPHYTA (MOSSES & LIVERWORTS)

The remaining "lower plants" are all true plants in that they develop from an embryo and thus, are multicellular. Within the plant kingdom there are two basic groups: the bryophytes (nonvascular plants) and the tracheophytes (vascular plants). Bryophytes are intermediate between algae and the higher plants. They have hair-like rhizoids that function as roots, but lack true vascular tissue. Most are rather inconspicuous plants growing in moist environments. They are not fully adapted to life on land in that their sperm must swim thorough water to reach their eggs (Margulis and Schwartz 1988). Because bryophytes lack the fluid-conducting tissues of the vascular plants (xylem and phloem), they also rely on surrounding water to conduct necessary fluids and salts during times of growth, but many are able to survive periods of desiccation. Although no detailed study of the bryophytes has been undertaken in the Old Woman Creek watershed, 156 different species have been reported from the region, including *Barbula indica* var. *indica* (twisted teeth moss), a listed rare plant in Ohio. Both Phillips (1997) and Whyte (1996) have reported bryophyte species from the Old Woman Creek watershed.

Class Hepaticopsida (liverworts)

Liverworts have a vegetative body (thallus) that is a somewhat fleshy, leaflike mass growing flat on moist soil or floating on the surface of a water body. The thallus carries out the main functions that in a flowering plant would be done by the roots and leaves. Distinct male and female organs are visible during the growing season. A few species of aquatic liverworts have been identified in the estuary, where they float free in the water or grow on the mud flats along the shore. *Ricciocarpus natans* has a leafy, lobed thallus that floats at the surface like duckweed, while *Riccia fluitans* normally occurs just below the surface, spreading slender branches to form a bright green network.

Class Sphagnopsida (peat mosses)

This class contains only the genus *Sphagnum*, which has been divided into over 100 species. Several species have been identified in the region surrounding the estuary, but not within the Reserve. Peat mosses are boreal plants of lowland habitats and Ohio lies near the southern limit of their range. Biologically, these plants are important because of their ability to retard decomposition, acidify their surroundings, and hold large quantities of water. All peat mosses have two types of leaf cells: small, green ones for photosynthesis and large, dead ones for water storage. *Sphagnum palustre* forms compact mats that can extent over large areas of quiet waters, at times forming floating islands that can support the weight of a person.

Class Bryopsida (true mosses)

Mosses frequently cover large areas of stream banks, grow on rocks and trees, and a few live submerged in flowing water. They grow crowded together like liverworts and lichens, with which they are commonly associated. However, their flat green leaves distinguish them from these two associates, neither of which bear leaves. Many mosses anchor their cushiony stems to the soil by a branched rootlike system of rhizoids. They are not true absorbing roots and they have no special conducting tissue in their leaves and stems. Although some mosses can survive drought conditions, all require moisture for active growth and reproduction. The hair–cap moss, *Polytrichum commune*, often forms pure stands that are several meters across with stems up to 30 cm long. Male and female organs are borne on separate plants. Sperm cells swim to the egg cells, which, when fertilized, form spores within a capsule. When the spore are released, if they land in an area with sufficient moisture, they will germinate and produce vegetative filaments (protonema). The twisted teeth moss, *Barbula indica* var. *indica*, which has been reported for Erie County, is listed on the rare plant inventory for the State of Ohio.

DIVISION LYCOPODIOPHYTA (CLUBMOSSES)

Class Lycopodiopsida

The clubmosses are relicts of the ancient scale trees that once dominated the landscape during the latter part of the Paleozoic era and eventually became fossilized into the coal measures of southeastern Ohio. Modern lycopods are relatively inconspicuous and represented by a single genera, *Lycopodium*, in the vicinity of the Old Woman Creek watershed. This common clubmoss remains green all winter and has the appearance of a miniature pine tree. They are typically found in cool, moist woodlands, under maples, pines or oaks. The plant body consists of branching horizontal rhizomes (underground stems) and an upright part bearing branches and small leaves (microphylls) which are arranged in tight whorls on the aerial branches. Clubmosses bear no seeds, but produce spores which germinate into either male or female gametophytes. The majority of the records date back to Moseley (1899) and Easterly (1950). Phillips (1997) and Jones (1997) have added additional records.

DIVISION EQUISETOPHYTA (HORSETAILS)

Class Equisetopsida

Horsetails are easily recognized by their jointed, hollow stems and rough, ribbed texture. The roughness is caused by mineral silica concentrated in the epidermal cell of the green photosynthetic stems. The abrasive nature imparted by the silica accounts for another common name for these plants, scouring rush. The division is made up of a single herbaceous genus, *Equisetum*. They thrive on mud flats, along the banks of streams, in moist low wooded areas. In the Reserve, horsetails grow along the barrier beach and in the prairie remnant located southwest of the estuary's main basin. Like many other of the lower plants, horsetails produce spores which are borne by the wind.

DIVISION FILOPHYTA (FERNS)

Class Filicopsida

Ferns are familiar vascular plants of the woodlands that, like the bryophytes, lycopods, and equisetophytes, reproduce by means of spores, rather than seeds. Spores do not carry a food store for nourishment during germination as found in the seeds of higher plants. Unlike the other lower plants, ferns do have leaves, called megaphylls or fronds, that develop directly from the main photosynthetic stem (Figure 6.11). Because their fertilization also requires the swimming of the sperm cell, ferns are limited to habitats that are at least occasionally moist. Fern fronds unroll from curled structures known as "fiddleheads." The fronds are usually compound, being divided into leaflets called pinnae that may be subdivided further into pinnules. The margins or edges may be entire (not toothed or cut), toothed, or lobed. When the clefts are deep and the lobes are long and narrow, the frond margin is termed pinnatifid. A total of 18 species of ferns in 6 families occur within the Old Woman Creek watershed (Phillips 1997, Whyte 1996, Windus 1995, and Feix and Wright 1992).

*Figure 6.11. Spinulose wood ferns (*Dryopteris carthusiana*) and mosses abound on the sandstone outcrops of the Berea escarpment, north of Berlin Heights, Ohio (Charles E. Herdendorf).*

Higher Vascular Plants

The higher vascular plants possess a well-developed conductive system, structural differentiation (typically roots, stems, and leaves), and seeds. Higher plants are grouped into two divisions based on seed characteristics. Within the Research Reserve and the Old Woman Creek watershed 8 species of conifers (gymnosperms) and 829 species of flowering plants (angiosperms) have been reported (Appendix B). A detailed treatment of the vascular plants from the Old Woman Creek estuary and watershed is presented in Old Woman Creek SNP & NERR Technical Report No. 10: *Catalogue of the Vascular Plants in Old Woman Creek Estuary and Watershed* (Herdendorf et al. 1999a,2001c).

DIVISIONS

Division Pinophyta (gymnosperms or conifers)

A trait common to all gymnosperms is the absence of a protective case (ovary wall) around their seeds. This division is represented by several native and alien pines (e.g. *Pinus strobus* and *Pinus nigra*) in the Reserve and eastern hemlock (*Tsuga canadensis*) in the ravine at Berlin Heights. In pines and other cone-bearers, seeds are borne on the surface of scales that comprise the cone, and although well-protected by the scales, they are not surrounded by floral part.

Division Magnoliophyta (angiosperms or flowering plants)

The majority of visual terrestrial plants in the watershed are angiosperms, many of which produce attractive flowers. The seeds of these plants are borne within a closed structure (ovary), which eventually develops into the fruit. The flowering plants are subdivided into two classes based on the embryo's seed leaves (called cotyledons). In the monocots (class Liliopsida), a single narrow leaf first pierces the soil and stands erect (e.g. grasses, lilies, and orchids). In the dicots (class Magnoliopsida), which is the more common class, two broad leaves fall open as soon as they reach the soil surface with a seedling emerging from between them (e.g. most annuals, bushes, and trees). A total of 837 terrestrial and aquatic taxa have been identified in the watershed, two-thirds of which are found within the boundaries of the Reserve. About 78% are native and 22% are aliens (Marshall 1977).

HABITATS

As a transition zone between land and water, Old Woman Creek estuary and its immediate environs contain several distinct habitats, including upland woodlands, prairie remnants, creek valley, swamp forest, marshes, wooded coves, open waters of the estuary, an island, barrier beach, and nearshore Lake Erie (Figure 1.4). The estuary is the drowned mouth of a relatively small tributary to Lake Erie. The estuarine wetlands consists of 60 hectares that extend 2 km south of the Lake Erie shore. As the result of wave action and littoral drift, a barrier beach has formed at the mouth which bars off the estuary for extended periods. The barrier is periodically broken by storm flow from the watershed, but occasionally Lake Erie storm surges and seiches spill over the bar and into the estuary.

Moseley (1899) was the first botanist to document the vascular vegetation of Old Woman Creek watershed and his classic work, *Sandusky Flora*, forms the only comprehensive assessment of the flora in the study area. The vascular plants of the Reserve, particularly those associated with the estuary, were studied by Marshall and Stuckey (1974), Marshall (1977), Jones (1978), Francko and Whyte (1995a,b), Whyte (1996) and Trexel-Kroll (2002). Bernhardt (1996) and Phillips (1997) documented the flowering plants of certain holdings of the Erie County Metropolitan Park system within the Old Woman Creek watershed. Collectively, these botanists have provided us with an extensive understanding of the flora represented in the various habitats of the watershed. These will be discussed separately in this section and will include: (1) barrier beach, (2) estuary, (3) hardwood forests, (4) prairie, (5) ravines, and (6) old fields and rights-of-way margins (see Figure 1.4, p. 1-6).

Barrier Beach

A sandy barrier beach fronts the entire Lake Erie shore of the Research Reserve, a reach approximately 0.5 km long lying on the lakeward side of U.S. Route 6. The eastern section of the beach is backed by a small lagoon that is periodically connected to the lake via an inlet channel. The western section of the beach is backed by a lakeshore woodland and a small isolated pond that drains to the lake across the beach face.

Figure 6.12. Barrier beach at the mouth of Old Woman Creek estuary (Charles E. Herdendorf).

The exposed beach front is relatively free of vegetation, colonization being limited by wave action which constantly reshapes the foreshore (Figure 6.12). The xeric environment of the more protected upper beach and low dunes supports only sparse populations of mostly herbaceous species, including:

Abutilon theophrasti (velvet-leaf)
Acalypha rhomboidea (3-seed red mercury)
Astragalus canadensis (Canada milkvetch)
Ambrosia artemisiifolia (ragweed)
Amaranthus albus (tumbleweed)
Amaranthus retroflexus (pigweed)
Barbarea vulgaris (common winter-cress)
Bidens cernua (nodding beggarticks)
Bidens connata (beggarticks)
Bidens frondosa (beggarticks)
Sinapsia alba (white mustard)
Cakile edentula (inland sea-rocket)
Chenopodium album (lamb's-quarters)
Cyperus esculentus (yellow nut-grass)
Cyperus odoratus (rusty cyperus)
Cyperus rivularis (riverbank cyperus)
Digitaria sanguinalis (crab grass)
Echinochloa crus-galli (barnyard grass)
Eclipta prostrata (yerba-de-tajo)
Equisetum arvense (common horsetail)
Eragrostis pectinacea (purple lovegrass)
Euphorbia polygonifolia (seaside spurge)
Galinsoga parvifloria (galinsoga)
Hibiscus trionum (flower-of-the-hour)
Lindernia dubia (false pimpernel)
Ludwigia palustris (water-purslane)
Mirabilis nyctaginea (four-o'clock)
Oenothera biennis (evening primrose)
Panicum capillare (old witch grass)
Pilea pumila (richweed)
Plantago major (common plantain)
Polanisia dodecandra (clammy-weed)
Polygonum pensylvanicum (pinkweed)
Portulaca oleracea (common purslane)
Salsola kali (saltwort, Russian thistle)
Setaria faberi (Faber's foxtail)
Strophostyles helvula (wooly bean)
Xanthium strumarium (cocklebur)

Populus deltoides (cottonwood) and *Salix exigua* (sandbar willow) seedlings are scattered along the shore, particularly on the western section of the barrier beach. *Rhus typhina* (staghorn sumac) and *Vitis riparia* (riverbank grape) stretch the length of the west beach, occupying a transition zone between open sand and a bordering woodland that extends south to U.S. Route 6.

The backshore of the barrier beach, where it forms the shore of the lake lagoon, exhibits a plant community that is more dependent on wetland conditions. *Phragmites australis* (common reed) forms large monotypic stands along the east and west banks of the inlet channel and extends the entire length of the lake lagoon's north shore. *Scirpus americanus* (three-square bulrush), *Scirpus fluviatilis* (river bulrush), *Impatiens capensis* (jewelweed), *Scutellaria laterflora* (mad-dog skullcap), and *Lycopus americanus* (American water horehound) are locally scattered along the backshore. *Triplasis purpurea* (purple sand-grass) and *Panicum virgatum* (switchgrass) are more common and occupy more open areas higher on the backshore.

ESTUARY

Old Woman Creek estuary is comprised of three major sub-habitats, including: (1) the open waters of the basins, (2) embayments, mudflats, and low shorelines, and (3) swamp forests. These estuarine habitats in turn contain distinct zones of vegetation. These zones contain plants of similar form and degree of adaptation to aquatic life but not necessarily phylogenetic affinity (Arber 1920). The relative proportion of the open water versus mudflat habitats is largely regulated by annual water levels in Lake Erie (when the mouth is open) and in the estuary proper (when the mouth is closed).

Open Waters

The open waters of the estuary are characterized by dense, monotypic beds of *Nelumbo lutea* (American water lotus) which extend south from the U.S. Route 6 bridge, through the main basin of the estuary, and into the south basin (Figure 6.13). In mid-1990s, *Nelumbo* beds covered up to 40% of the estuary surface

*Figure 6.13. Cove enbayment on Old Woman Creek estuary leading to the open water of the main basin. A massive bed of American water lotus (*Nelumbo lutea*) can be seen at right center (Gene Wright).*

during the peak growing season (Whyte 1996), whereas in the mid-1970s, lotus beds occupied only 10% of the estuary (Marshall 1977). Record high water levels in Lake Erie in the mid-1970s (approximately 0.5 m above mid-1990s levels) appear to be the cause of the sparse development of lotus beds during that period.

Other aquatic plants that are occasionally associated with the *Nelumbo* beds or occur in patches scattered throughout the open waters of the estuary include:

Ceratophyllum demersum (coontail)
Elodea canadensis (common water-weed)
Lemna minor (lesser duckweed)
Myriophyllum spicatum (water milfoil)
Nuphar advena (yellow water-lily)
Nymphaea odorata (white water-lily)
Peltandra virginica (arrow-arum)
Potamogeton crispus (curly pondweed)
Potamogeton foliosus (leafy pondweed)
Potamogeton nodosus (knotty pondweed)
Potamogeton pectinatus (sago pondweed)
Riccia fluitans (crystalwort)
Ricciocarpus natans (aquatic liverwort)
Spirodela polyrrhiza (greater duckweed)

During high lake level periods, beds of water smartweed (*Polygonum amphibium* var. *emersum*) develop on the submerged natural levies of the south basin (Figure 6.14). An isolated population of *Myriophyllum spicatum* was first documented in the estuary in 1992 and scattered patches were found in 1995 immediately north of Star Island on the perimeter of Nelumbo beds and along the main channel of the creek through the estuary (Whyte 1996).

Embayments and Mudflats

The Old Woman Creek shoreline is characterized by steep banks that support dense growths of woody riparian vegetation (Figure 6.13). Common species, such as *Quercus alba* (white oak), *Quercus palustrus* (pin oak), *Salix exigua* (sandbar willow), *Cornus florida* (flowering dogwood), *Cornus drummondii* (rough-leafed dogwood) *Cephalanthus occidentalis* (buttonbush), *Populus deltoides* (cottonwood), and *Vitis riparia* (river-bank grape), form a closed canopy which limits sunlight available to understory and shoreline emergent vegetation (Whyte 1996). The combination of a closed canopy and steep bluffs reduces the amount of habitat for the growth of emergent wetland vegetation to a narrow zone along the shoreline. Typical plants of this zone include: *Hibiscus moscheutos* (swamp rosemallow, Figure 6.15), *Impatiens capensis* (jewel-weed), *Iris versicolor* (blue-flag), *Leersia orzyoides* (rice cut-grass), *Phalaris arundinacea* (reed canary-grass), *Pilea pumila*

*Figure 6.14. Water smartweed (*Polygonum amphibium *var.* emersum*)*
on flooded natural levies of the south estuary basin (John Marshall).

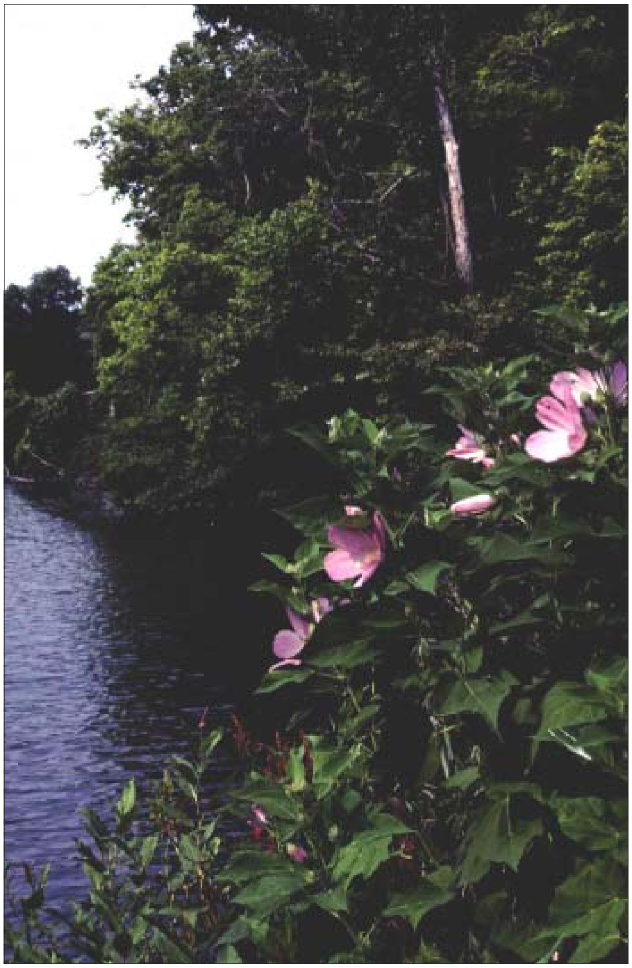


*Figure 6.15. Swamp rosemallow (*Hibiscus moscheutos*) fringing the shore of Old Woman Creek estuary (Charles E. Herdendorf).*

(clearweed), *Lobelia inflata* (Indian tobacco), *Ranunculus hispidus* (hispid buttercup), *Scutellaria lateriflora* (skullcap), *Solanum nigrum* (black nightshade), and *Carex* spp. (sedges). Along the base of the estuary bluffs and extending out into the open water, numerous fallen trees have accumulated debris to form micro-habitats with suitable substrate for herbaceous species such as *Setaria faberi* (foxtail-grass), *Carex comosa* (sedge), *Eclipta prostrata* (yerba-de-tajo), *Polygonum persicaria* (lady's thumb), and *Rorippa palustris* (common yellow cress).

From the inception of the Research Reserve through 1999, the emergent flora was confined to the very shallow embayments in the estuary. However, the lower Lake Erie water levels from 1999 to date have resulted in extensive mudflat areas in the estuary, where there was open water a few years before.

In 1977, Marshall reported that the embayment areas had a high diversity, with many areas not having a distinct dominant species. Among the common species were: *Peltandra virginica*, *Leersia oryzoides*, *Phalaris arundinaceae*, *Calamagrostis canadensis*, *Typha latifolia*, *Sparganium eurycarpus*, and various *Scirpus* and *Carex* species. Whyte (1996) examined many of these embayments 20 years later and reported many of the same species. However, Whyte noted that *Phragmites australis* was frequently found in this habitat, a species not reported by Marshall. By 2000 with falling lake water levels, these shallow mudflat embayment areas accounted for a large portion of the estuary. Trexel-Kroll (2002) also found some similarity in species composition with these earlier studies with a few exceptions. *Peltandra virginica*, although present, was uncommon. The grasses *Leersia oryzoides* and *Echinochloa* spp. increased in importance from 2000 through 2001. *Phragmites australis* was also expanding its coverage during these two years. By 2002 *Phragmites australis* and *Typha angustafolia* had assumed dominance over much of the estuary.

Along some reaches of the estuary shore (e.g. west bank north or Star Island), steep bluffs give way to open areas of low relief with associated mudflats and seasonally inundated floodplains. These aquatic areas currently (2004) support extensive monotypic colonies of *Phragmites australis* (common reed). With the exception of the climbing vines of wild cucumber (*Echinocystis lobata*), few other plants are associated with *Phragmites* stands. This reed is a recent invader, first appearing on the shores of the estuary in the mid-1980s (Whyte 1996).

Swamp Forest

Areas of wet woods are found in two embayments along the east shore where seasonally flowing streams enter the estuary. A much larger lowland or swamp forest borders the southern reaches of the estuary (Figure 6.16). Common woody species in these areas are *Cephalanthus occidentalis* (buttonbush), *Fraxinus americana* (white ash), *Fraxinus pennsylvanica* (green ash), *Quercus rubra* (red oak), *Crataegus mollis* (downy hawthorn), *Cornus florida* (flowering dogwood), and *Viburnum acerifolium* (arrowwood). Numerous herbaceous plants appear early in the growing season, including *Phalaris arundinacea* (reed canary grass) on, *Caltha palustris* (marsh marigold), *Ranunculus flabellaris* (yellow water buttercup), and

*Figure 6.16. Swamp forest in south estuary basin. Emergent beds of spatterdock (*Nuphar lutea*) in foreground (Gene Wright).*

Anemonella thalictroides (rue anemone). In total, 102 species of woody and herbacious species have been reported for these wet woodlands (Windus 1995).

Windus (2002) monitored the species composition and relative abundance in the swamp forest from 1987 through 2000. By 2000 the most common woody plants were *Fraxinus pennsylvanica*, *Cephalanthus occidentalis*, and then *Viburnum recognitum*. Through the duration of the sampling period, both *Fraxinus* and *Viburnum* declined in relative abundance while *Cephalanthus* remained about the same. The most common herbaceous plants included *Phalaris arundinacea*, *Polygonum* spp., *Sagittaria latifolia*, and less frequently *Typha* spp., *Scirpus fluviatilis*, and *Boehmeria cylindrical*. Many of the native species reported in the early years of this study have declined including the woody plants *Salix*, *Populus deltoides*, *Cornus sericea* and *Lindera benzoin*. These declines were believed related to declining water levels in the estuary. Windus (2002) expressed concern about the impact and fate of invasive species, particularly *Phalaris arundinacea* and *Phragmites australis*, which have entered the swamp forest during the study and have increased abundance through the end of this study.

Hardwood Forests

The majority of the terrestrial (upland) habitats within the Research Reserve are covered with mixed hardwood forest. Three forest associations are present on the upland portions of the Reserve and other wooded areas of the Old Woman Creek watershed: (1) oak-hickory, (2) maple, and (3) sassafras-oak-hickory (Marshall 1977). The oak-hickory association occupies the steep banks on the eastern and western sides of the Reserve. This association is dominated by *Quercus alba* (white oak) and *Carya ovata* (shagbark hickory), with several accompanying woody species, including *Q. palustris* (pin oak), *Q. borealis* (red oak), *Fraxinus americana* (white ash), *Viburnum prunifolium* (black haw), and *Sassafras albidum* (white sassafras). *Trillium grandiflorum* (large-flowered trilium), *Arisaema atrorubas* (Jack-in-the-pulpit), *Erythronium americanaum* (yellow trout-lily), and *Viola* spp. (violets) are conspicuous herbaceous associates in the spring (Figures 6.17 and 6.18), while *Cimicifuga*

*Figure 6.17. Large-flowered trillium (*Trillium grandiflorum*) in a hardwood forest of the Research Reserve (Charles E. Herdendorf).*

*Figure 6.18. Freckled blue violet (*Viola sororia*) in the upland woods west of estuary (Charles E. Herdendorf).*

racemosa (black cohosh) and *Lobelia cardinalis* (cardinal flower) bloom in July, particularly in forest openings along the east bank of the estuary (Figure 6.19). South of the northern railroad bridge, the eastern upland forest merges with a swamp forest on the inundated Old Woman Creek floodplain. On the western uplands, south of the railroad, a small plantation of *Pinus strobus* (white pine) thrives within the oak-hickory forest.

The maple forest association occupies a small area on the eastern bluff at the mouth of the estuary. This is a lakefront woodland that lies on the north side of U.S. Route 6. Dominant trees at this site are *Acer saccharinum* (silver maple) and *Acer rubrum* (red maple). Associated woody species include *Populus deltoides* (cottonwood), *Hamamelis virginiana* (witch hazel), *Rhus glabra* (smooth sumac), and *Cornus florida* (flowering dogwood).

The sassafras-oak-hickory association exists on Star Island near the center of the main basin of the estuary. This woodland is dominated by *Sassafras albidum* (white sassafras), with *Quercus alba* (white oak) and *Carya ovata* (shagbark hickory) comprising

*Figure 6.19. Cardinal flower (*Lobelia cardinalis*) in a cove depression along the Edward Walper Trail east of Old Woman Creek estuary (Gene Wright).*

the major woody associates. Individuals of these three taxa are generally younger than those found in the woodlands on the eastern and western uplands adjacent to the estuary, indicating more recent clearing on the island. Herbaceous dominants of the spring flora are *Trillium grandiflorum* (large-flowered trilium) and

Podophyllum peltatum (may–apple). These taxa are significantly more abundant on Star Island than in any other woodland in the Reserve (Marshall 1977).

PRAIRIE

While most of the upland areas of the Research Reserve are either woodlands or old farm fields, a small grassland prairie occurs along the railroad right-of-way at the western side of the Reserve. This 2-hectare site is unlike the old fields on the Reserve, in that its species composition includes many plants commonly associated with prairie habitats found in western Ohio and northeastern Illinois (Jones 1944, Vestal 1914). Conditions in the Reserve support nearly 50 herbaceous species that comprise an upland prairie community (Figure 6.20):

Andropogon gerardii (big bluestem)*
Anemone virginiana (thimbleweed)*
Apocynum sibiricum (clasping-leaf dogbane)
Asclepias syriaca (common milkweed)*
Asclepias tuberosa (butterfly-weed)*
Aster dumosus (bushy aster)
Aster novae-angliae (New England aster)
Aster undulatus (aster)
Cacalia atriplicifolia (pale Indian-plantain)
Carex cephalophora (sedge)
Carex lasiocarpa (slender sedge)
Carex pensylvanica (sedge)
Carex retroflexa (reflexed sedge)
Ceanothus americanus (New Jersey tea)
Celastrus scandens (American bittersweet)
Cirsium vulgare (bull thistle)
Clematis virginiana (virgin's bower)
Conyza canadensis (horseweed)
Coreopsis tripteris (tall tickseed)
Epipactis helleborine (helleborine)
Equisetum arvense (common horsetail)
Euphorbia corollata (flowering spurge)*
Euphorbia dentata (toothed spurge)
Helianthus divaricatus (sunflower)
Helianthus tuberosus (Jerusalem artichoke)
Heliopsis helianthoides (Sweet ox-eye)
Hydrangea arborescens (wild hydrangea)
Lactuca canadensis (wild lettuce)
Lespedeza capitata (bush clover)*
Lespedeza virginica (bush clover)*
Lilium michiganense (Michigan lily)
Melilotus officinalis (yellow sweet clover)
Panicum virgatum (switchgrass)*
Pycnanthemum virginianum (mountain mint)
Rhus glabra (smooth sumac)
Rudbeckia hirta (black-eyed Susan)
Silphium trifoliatum (rosinweed)*
Sisyrinchium albidum (blue-eyed grass)
Sisyrinchium mucronatum (blue-eyed grass)
Solidago juncea (early goldenrod)
Sorghastrum nutans (Indian grass)*
Spiranthes cernua ((nodding ladies'-tresses)*
Spiranthes magnicamporum (ladies'-tresses)
Symphytum officinale (common comfrey)
Veronicastrum virginicum (Culver's-root)

* most common prairie species in Old Woman Creek estuary

*Figure 6.20. Prairie habitat in the Research Reserve. American bittersweet (*Celastrus scandens*) in the foreground and tall prairie grasses in the background (Charles E. Herdendorf).*

occuring at the Old Woman Creek site with species reported for Castalia Prairie in western Erie County, Ohio (Hurst 1971), prairie remnants in northwestern Ohio (Anderson 1971, Jones 1944) and black-soil prairies of northeastern Illinois (Vestal 1914). Of eleven major prairie-related taxa identified at Old Woman Creek (* in above list), Marshall found that all occured in at least three of the four prairie areas surveyed. He also found that *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indian grass) were the dominant plants at the Old Woman Creek site—two of the four species that Vestal (1914) considered to be dominant among Ohio's prairie flora.

The soils underlying the prairie site are classified as Sission loamy fine sand and silt loam (Redman et al. 1971). Sission soils are well-drained, granular, and friable, often occurring on the top and sides of knolls. The prairie site is situated at the crest of a bluff that is exposed to the dominant southwesterly winds. These conditions are favorable for the development of prairie plant communities, particularly exposure to sun and wind along the railroad right-of-way. Vestal (1914) pointed out that disturbances, such as burning and mowing, associated with rights-of-way are beneficial to the maintenance of prairies in Ohio. Marshall (1977) reported the occurrence of charred material in the soil at the site, indicating that fire initiated by sparks from passing rail cars was a likely disturbance which periodically rejuvenated the prairie.

OLD FIELDS AND RIGHT-OF-WAY MARGINS

Old fields in the vicinity of the Reserve are in various stages of succession depending on the period of time that has elapsed since the field was last tilled, mowed, or burned (Figure 6.21). The most recently abandoned fields are characterized by *Ambrosia artemisiifolia* (common ragweed), *Ambrosia trifida* (giant ragweed), *Polygonum pensylvanicum* (pinkweed), *Rhus glabra* (smooth sumac), *R. typina* (staghorn sumac), *Stachys tenuifolia* (hedge-nettle), *Aster* spp., and *Solidago* spp. (goldenrods). At a later successional stage, shrub plants become more prevalent, including *Cornus* spp. (dogwoods), *Crataegus* spp. (hawthorns), and *Salix* spp. (willows), then saplings of *Carya ovata* (hichory), *Sassafras albidum* (white sassafras), and *Quercus* spp. (oaks).

The margins of U.S. Route 6, the Conrail embankment, and other transportation rights-of-way in the vicinity of the Research Reserve represent another type of disturbed terrestrial habitat that is dominated by herbaceous, pioneer species. In these continually disturbed areas, many of the species are non-native "weedy" plants such as, *Chaenorrhinum minus* (dwarf snapdragon), *Epipactis helleborine* (helleborine), *Hemerocallis fulva* (orange day-lily), *Linaria vulgaris* (butter-and-eggs), *Melilotus albus* (white sweet clover), *Melilotus officinalis* (yellow sweet clover), *Sedum telephium* (garden orpine), and *Saponaria officinalis* (soapwort). These "weedy" species are capable of surviving severe chemical and physical disturbances and frequently displace native vegetation (Marshall 1977).

RAVINES

At Berlin Heights, Old Woman Creek has cut a picturesque ravine through the Berea Sandstone and into the Ohio Shale (Figures 2.22 and 2.28). Here, Moseley (1899) found several unusual plants not found farther west in Erie and Ottawa counties. The walls of the deep ravines of Old Woman Creek, Chappel Creek, and the Vermilion River, like the wall of a cellar, are warmed slowly in the summer so that the north sides of the steep, wooded slopes are some of the coolest places in the region; hence they support many plants which are more common farther to the north and east, including:

Asplenium rhizophyllum (walking fern)
Cacalia atriplicifolia (Indian plantain)
Cardamine diphylla (two-leaved toothwort)
Carex pedunculata (sedge)
Cypripedium reginae (showy lady-slipper)
Dichanthelium depauperatum (panic-grass)
Dryopteris marginalis (marginal wood-fern)
Gaultheria procumbens (wintergreen)
Gentianopsis detonsa (fringed gentian)
Hieracium paniculatum (hawkweed)
Hydrophyllum canadense (waterleaf)
Isopyrum biternatum (false rue-anemone)
Jeffersonia diphylla (twinleaf)
Maianthemum canadense (false lily-of-valley)
Mitchella repens (partridge-berry)
Polypodium virginianum (common polypody)
Polystichum acrostichoides (Christmas fern)
Rubus odoratus (flowering raspberry)
Scutellaria nervosa (skullcap)
Thelypteris hexagonoptera (beech-fern)
Tsuga canadensis (hemlock)
Vaccinium pallidum (hillside blueberry)

Figure 6.21. Old field habitat found along the Edward Walper Trail in the Research Reserve (Charles E. Herdendorf).

INVERTEBRATE FAUNA

Invertebrate is the name given to any of the animals or animal-like organisms without backbones as contrasted with the vertebrates (e.g. fish, amphibians, reptiles, birds, and mammals), all of which have a vertebral column. Taxonomically, invertebrates are grouped into some 37 phyla in two kingdoms: Protista and Animalia. Representatives of 13 of the invertebrate phyla have been identified in Old Woman Creek estuary and watershed, and the adjacent waters and tributaries of Lake Erie. Altogether, a total of 1,373 taxa of aquatic and terrestrial invertebrates have been documented from the study area: 318 protozoan, 4 sponge and hydroid, 7 flatworm and gastrotrich, 34 rotifer, 3 nematode, 33 mollusk, 46 annelid worm and leech, 77 spider and water mite, 87 crustacean, 758 insect, and 6 tardigrade and bryozoan species. Nearly 60% of these taxa are found within the boundaries of the Research Reserve (Appendix C). A detailed treatment of the invertebrates is contained in Old Woman Creek SNP & NERR Technical report No. 12: *Catalogue of the Invertebrate Fauna of Old Woman Creek Estuary, Watershed, and Adjacent Waters of Lake Erie* (Herdendorf et al. 2000b,2001b).

PROTISTA: PROTOZOAN INVERTEBRATES

Protozoans consist of a large group of unicellular animals that have adapted their cell to serve as their entire body. Classified as a subkingdom of the Kingdom Protista, protozoans are not simple organisms. Within a single cell they must perform all of the body functions for which higher animals have multiple organ systems. Protozoans live under almost all natural conditions where moisture is found (Jahn et al. 1979). Within Old Woman Creek estuary and watershed researchers have identified 318 taxa of these microscopic creatures (Figure 6.22).

The locomotor organelles of Protozoa are used to separate them into major taxonomic groups. These organelles include: (1) undulipodia, which possess cilia or flagella and (2) pseudopodia, which are elongated extensions of the body formed by protoplasmic flows. To propel the cell, undulipodia produce rotary, undulatory, and helical wave motions, whereas pseudopodia create flowing motions (Pearse et al. 1987). The protozoan taxa reported for Old Woman Creek estuary are listed in Table 6.3.

PHYLUM SARCOMASTIGOPHORA

The sarcomastigophorans include both flagellated and amoeboid protozoans, thus the phylum is divided into two subphyla based on the type of locomotion organelles. The mastigophorans possess flagella, whereas the sarcodines utilize pseudopodia.

Subphylum Mastigophora

Mastigophorans are protozoans that have one or more flagella. Some are plant-like and contain green chloroplasts (chromatophores), such as the dinoflagellates, phytomastigophores, and euglenoids. Thus, many of the species in this subphylum can also be classified as algae. Others are more animal-like and lack chloroplasts, such as the zoomastigophores.

Class Dinoflagellata. Dinoflagellates differ from other mastigophores in having a transverse groove or "girdle" holding a circumferential flagella. The groove typically has a posterior extension which has a second (longitudinal) flagellum. The body is commonly armored with thick cellulose plates ranging in color from reddish-brown to yellow. The anterior part of an armored cell is referred to as the epitheca and the posterior part is the hypotheca. Dinoflagellates are a major food source for aquatic organisms. The genus *Gymnodinium*, which is a benthic inhabitant of the estuary, has green chloroplasts but lacks a protective cellulose case (theca).

Class Phytomastigophora. Three orders of this class comprise common benthic groups in the estuary: cryptomonads, chrysomonads, and volvoceans. Cryptomonads are very small, flattened protozoans with distinct reservoir pockets and yellow to brownish-green chloroplasts. Chrysomonads are also very small protozoans that possess a variety of features including spines, pallmella (group of cells in a gelatinous matrix), lorica (loose fitting sheath), branched stalk, and colonial arrangements. Volvoceans are larger solitary or colonial protozoans with cellulose walls through which 2 to 8 flagella extend from each cell.

Class Euglenea. Euglenoids are flagellates that typically have grassy green chloroplasts and reddish sigma (eyespot with photoreceptive function). They store carbohydrates as granules in an anterior reservoir

TABLE 6.3. CLASSIFICATION OF PROTOZOANS REPORTED FOR OLD WOMAN CREEK ESTUARY

	Taxa Reported		Undulipodia Cilia	Undulipodia Flagella	Pseudopodia
SUBKINGDOM PROTOZOA					
Phylum Sarcomastigophora	198				
Subphylum Mastigophora		145		•	
Class Dinoflagellata		2		•	
Class Phytomastigophora		48		•	
Class Euglenea		60		•	
Class Zoomastigophora		35		•	
Subphylum Sarcodina		53		•	
Class Lobosa		33			•
Class Filosa		4			•
Class Granuloreticulosa		2			•
Class Heliozoa		14			•
Phylum Ciliophora	120		•		
Class Kinetofragminophora		53	•		
Class Oligohymenophora		28	•		
Class Polyhymenophora		39	•		

(Ruppert and Barnes 1994). The family Trachelomonadidae consists of euglenoids that are each housed in a self-secreted lorica of various shapes. The order Peranemida are colorless euglenoids that obtain their nutrition by absorbing dissolved food through the cell membrane (saprobic) or by the ingestion of organic material as animals must do (holozoic). They exhibit a distinct gullet in contrast to the indistinct gullet of the pigmented euglenoids.

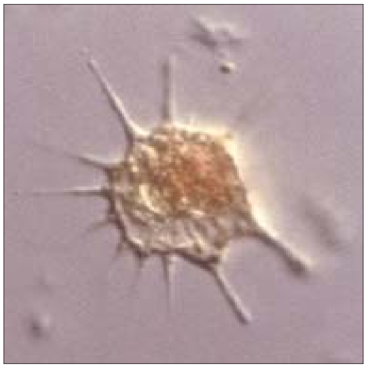
The organisms known as "euglenoids" constitute a controversial group in terms of the traditional plant versus animal debate. Most euglenoids are chlorophyll-bearing (chlorophytes), protozoa-like organisms of the Protista, and as such the chlorophytes can be considered members of the algal Division Euglenophyta (Taft and Taft 1971).

Class Zoomastigophora. These mastigophorans lack chloroplasts and stigma. Members of the family Codonosigidae typically have a transparent, ovoid body with a protruding collar that encircles a flagellum. Some individuals resemble collared cells lining the incurrent channels of sponges, suggesting an evolutionary relationship. Codonosigids are solitary or colonial, some loricate, and some stalked. The other common family in Old Woman Creek, Bodonidae, has two flagella and kinetoplasts (a replicating structure located near the base of the flagella). Nutrition is holozoic or coprozoic (ingestion fecal pellets that have been enriched by microbial activity).

Subphylum Sarcodina

Sarcodina are distinguished by their movement, which is by induced protoplasmic flow, and by their pseudopodia, which are temporary cytoplasmic extensions. Pseudopodia can be long and thin (axopodia), tapered and branched (filopodia), granular and interweaving in an anastomosing fashion (granuloreticulopodia), large and finger-like (lobopodia), or polytubular (myxopodia). Pseudopodia are used to capture food as well as aid in locomotion. Four classes of these protozoans have been identified in Old Woman Creek estuary.

Class Lobosa. This large class contains protozoans that more commonly known as "amoebas" as well as their close relatives which form tests (or shells). Amoebas typically form lobopodia of various



Amoeba sp.

Bodo saltans (SEM)

Codonella cratera

Cyclidium sp.

Halteria grandiniella

Rimsotrombidium lacustris

Stylonychia sp.

Urotricha farcta

Figure 6.22. Representative protozoans found in Old Woman Creek estuary (Peter J. Lavrentyev).

types which facilitate locomotion. The family Difflugiidae, represented in the estuary by several benthic species, form shells composed of mineral particles that are ingested by these protozoans and embedded in the shell in a secreted matrix (Ruppert and Barnes 1994).

Class Filosa. Members of this class found in Old Woman Creek feed on algae. *Vampyrella lateritia* has a round bright orange body, the color imparted by carotinoid granules derived from algal food. Using filopodia that resemble suctorial tentacles, these protozoans enter algal cells by digesting a hole in the cellulose wall of the alga, insert pseudopodia and digest the internal protoplasm, and then move to the next cell to repeat the process (Jahn et al. 1979). In this manner *Vampyrella* destroys many filamentous algae, including the green alga *Mougeotia*.

Class Granuloreticulosa. Most of the protozoans in this group form a calcareous test from which, through small pores, the granuloreticulopodia are extended in bundles that branch to form interweaving networks around the body (Jahn et al. 1979). In Old Woman Creek estuary this class is represented by *Biomyxa vagans* in the order Athalamida and *Diplophrys archeri* in the order Foraminiferida.

Class Heliozoa. These delicate protozoans have spherical bodies with many radiating axopodia; hence their common name, "sun animalcule." *Actinophrys sol*, found in Old Woman Creek, is a typical freshwater form of this group. Some members, such as the genus *Heterophrys*, have skeletons composed of silica secreted by the organism and embedded in an outer gelatinous covering.

PHYLUM CILIOPHORA

The ciliates propel their bodies and feed with short cilia (undulipodia) or a group of cilia (cirri). Many species have two types of nuclei, large ones (macronuclei) and small ones (micronuclei). Many ciliates have cilia in rows on the body or in tufts, but no specialized cilia around the mouth. In other ciliates, cilia are grouped in or around the mouth, as well as in rows along the body (Figure 6.23).

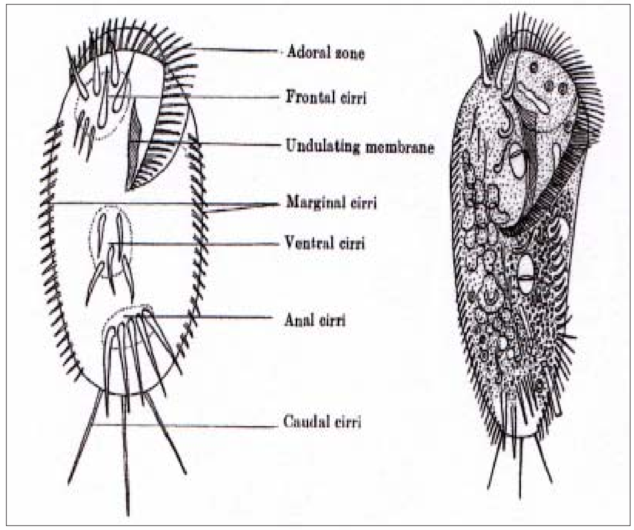


*Figure 6.23. Example of a ciliated protozoan (*Stylonychia mytilus*) found in Old Woman Creek estuary (from Kudo 1939).*

Class Kinetofragminophora. Members of this class lack cilia as special organelles around or in the mouth. However, some members of the order Prostomatida have club-shaped tactile cilia around the mouth. *Coleps octospina,* representative of this class in the estuary, has a barrel-shaped body with eight posterior spines. Ciliates in the order Haptorida found in the estuary are rapacious carnivores, such as *Didinium nasutum* which preys on *Paramecium*. Members of the order Suctorida have cilia only as larvae; adults are sessile with sucking and piercing tentacles used to catch prey and extract the cytoplasm. The suctorean *Acineta*, has a short stalk which is commonly attached to algae on the carapaces of turtles.

Class Oligohymenophora. These ciliates have either a series of cilia or an undulating membrane that curves counter-clockwise along the rim of the mouth cavity. The common, and extensively studied, aquatic genera *Paramecium* and *Tetrahymena* are members of this class and are residents of the estuary. These ciliates possess water expelling vesicles that eliminate excess water engulfed during the feeding process. Members of the suborder Sessilina of the order Peritrichida, such as *Vorticella campanula*, are often attached by a self-produced stalk to a variety of substrates in aquatic habitats, but large peritrichs have been reported in western Lake Erie plankton (Herdendorf and Monaco 1983). Planktonic *Vorticella* are often associated with blooms of blue-green alga *Anabaena flos-aqua*.

Class Polyhymenophora. These ciliates all have a band of membranelles (fused rows of cilia) arranged clockwise around or leading to the mouth. Members of the order Hypotrichida scuttle about on their ventral cirri (tufts of cilia fused together to form stiff, motile structures) as if they had tiny legs. In the estuary, *Stylonychia* is typical of this order with distinct frontal, ventral, anal, and caudal cirri (Kudo 1939). In the family Tininnidae of the order Oligotrichida, the transparent body of *Tinntinnidium fluviatile* is attached inside a trumpet-shaped lorica. The lorica is commonly impregnated with an agglomeration of sediment particles and is attached to submerged vegetation in the estuary.

ANIMALIA INVERTEBRATES

All animalia invertebrates are heterotrophs, in that they must obtain energy in the form of organic food produced by other organisms. Most of the distinctive characteristics of animals are associated with the requirements of finding, engulfing, and digesting food (Parker 1982). Animalia invertebrates from 11 phyla have been identified in the Old Woman Creek study area, altogether yielding 1,055 species (Table 6.4 and Appendix C).

PHYLUM PORIFERA

This phylum includes small freshwater sponges that are occasionally found in freshwater wetlands. They live in colonies, forming finger-like lobes, cushion-shaped masses, or encrusting patches. Because sponges do not require sunlight, they often live on the underside of submerged logs and other objects, commonly in association with bryozoan colonies and zebra mussels. Sponges of the estuary, Family Spongillidae, do not have specialized organs and are made up of a loose network of cells supported by siliceous spicules embedded in a collagen binder known as spongin (Thorp and Covich 1991). The chief food sources for sponges are very fine particulate matter and planktonic organisms suspended in the water column. As sedentary animals, they obtain their food by filtering the water that surrounds them through a series of pores located on the outer surface of their body.

PHYLUM CNIDARIA

This phylum, also known as Coelenterata, is primarily composed of marine members and has been relatively unsuccessful in adapting to freshwater except for the class Hydrozoa. In Old Woman Creek watershed two species of this class have been identified, the brown hydra (*Hydra americana*) from the estuary and a freshwater jellyfish (*Craspedacusta sowerbyi*) from an abandoned sandstone quarry pit (Baillie Quarry) 3.4 km northeast of Berlin Heights. The polyps of hydras are common on many hard, submerged surfaces, while the medusoid jellyfish are rare and seemingly absent for a number of years. The body wall of cniderians is characterized by three layers, a thin acellular gel (mesoglea) sandwiched between two thicker cellular layers (ectoderm and endoderm) that surround a central body cavity. These animals capture most of their invertebrate prey with ectodermal batteries of stinging or sticky nematocysts.

PHYLUM PLATYHELMINTHES

In Old Woman Creek estuary this phyla is represented by 5 species in three orders of the class Turbellaria. Two of the orders (Catenulida and Neorhabdocoela) are considered micoturbellarians and members are typically less than 1 mm in length, whereas individuals of the other order (Tricladida) can reach up to 20 mm and are considered macroturbellarians. Triclads, also known as planarians, have been the subject of more study that the smaller orders. Turbellarians are unsegmented flatworms that live in benthic and epiphytic environments. Most flatworms scavenge bacteria, algae, and protozoans; however, triclads are predatory on other invertebrates. These animals have not been found in great numbers in the estuary, but they were reported as widespread in the sediment and on plants.

PHYLUM GASTROTRICHA

Gastrotrichs are microscopic, elongated animals that colonize sediments and submerged plant stems and leaves. One genus, *Chaetonotus*, has been identified in Old Woman Creek estuary. *Chaetonotus* feeds on organic debris, algae, protozoans, and bacteria which are swept into its terminal mouth by the beat of four ciliated tufts which are arranged in pairs on either side of the head (Kershaw 1983). The body wall is covered by a cuticle secreted by the epidermis and the dorsal

TABLE 6.4. CLASSIFICATION OF ANIMALIA INVERTEBRATES REPORTED FOR OLD WOMAN CREEK

	Taxa		
PHYLUM PORIFERA Class Demospongiae (horny sponges)	2		
PHYLUM CNIDARIA Class Hydrozoa (hydras)	2		
PHYLUM PLATYHELMINTHES Class Turbellaria (flatworms)	5		
PHYLUM GASTROTRICHA Class Chaetonotida (gastrotrichs)	2		
PHYLUM ROTIFERA (rotifers)	34		
Class Bdelloidea		3	
Class Monogononta		31	
PHYLUM NEMATODA Class Adenophorea (roundworms)	3		
PHYLUM MOLLUSCA	33		
Class Gastropoda (snails)		11	
Class Bivalvia (clams)		22	
PHYLUM ANNELIDA	46		
Class Hirudinea (leeches)		4	
Class Oligochaeta (segmented worms)		42	
PHYLUM ARTHROPODA	922		
Class Arachnida		77	
Order Araneae (spiders)			74
Order Acriformes (water mites)			3
Class Crustacea		87	
Subclass Branchiopoda			39
Order Cladocera (water fleas)			39
Subclass Ostracoda (seed shrimps)			9
Subclass Copepoda (water-hoppers)			25
Order Calanoida			9
Order Harpacticoida			4
Order Cyclopoida			12
Subclass Branchiura: Order Arguloida (fish lice)			1
Subclass Malacostraca			13
Order Isopoda (sow bugs)			2
Order Amphipoda (scuds)			4
Order Decapoda (crayfishes & shrimps)			7
Class Insecta	758		
Subclass Entognatha			4
Orders Collembola & Diplura (springtails & diplurans)			4
Subclass Ectognatha			754
Order Thysanura (bristletails)			1
Order Ephemeroptera (mayflies)			21
Order Odonata (damselflies & dragonflies)			51
Orders Blattaria & Mantodea (cockroaches & mantids)			4
Order Isoptera (termites)			1
Order Orthoptera (grasshoppers & crickets)			15
Order Dermaptera (earwigs)			4
Order Plecoptera (stoneflies)			4
Order Thysanoptera (thrips)			3
Order Hemiptera (true bugs)			78
Order Homoptera (cicadas, leafhoppers & aphids)			32
Order Neuroptera (nerve-wing insects)			12
Order Coleoptera (beetles)			179
Orders Mecoptera & Siphonaptera (scorpionflies & fleas)			3
Order Diptera (true flies)			127
Order Trichoptera (caddisflies)			74
Order Lepidoptera (butterflies & moths)			83
Order Hymenoptera (ants, bees & wasps)			52
PHYLUM TARDIGRADA: Class Eutardigada (water bears)	1		
PHYLUM BRYOZOA: Class Phylactoaemata (bryozoans)	5		

surface bears a series of spines and scales. Gastrotrichs have a relatively short life span—usually between 3 to 21 days.

PHYLUM ROTIFERA

Rotifers are small (<1 mm long) but active members of the aquatic community. The head characterized by a crown of feeding cilia (corona) that gives the appearance of revolving wheels—hence the group's scientific name "Rotifera" and the common name "wheel animalcules"—and a muscular pharynx with a set of hard jaws, the mastax. The cilia of the head region are also used for locomotion. Most species are transparent and many have a thickened, sometimes armored, body wall (lorica) that tapers to a tail-like projection called a foot. The foot contains glands that can secrete an adhesive material used to anchor the rotifer during feeding (Pearse et al. 1987). Thus these animals can be either planktonic or sessile. Some 34 taxa of rotifers have been identified for Old Woman Creek estuary and the adjacent waters of Lake Erie, in 2 classes, 3 orders, and 10 families (Figure 6.24). Rotifers occur in a variety of aquatic habitats, both benthic and planktonic. As a group, rotifers are considered generalist suspension feeders, consuming a wide variety of small animal prey and plants. However, certain species have highly specific food habits. Most rotifers are females—the male being diminutive and short-lived.

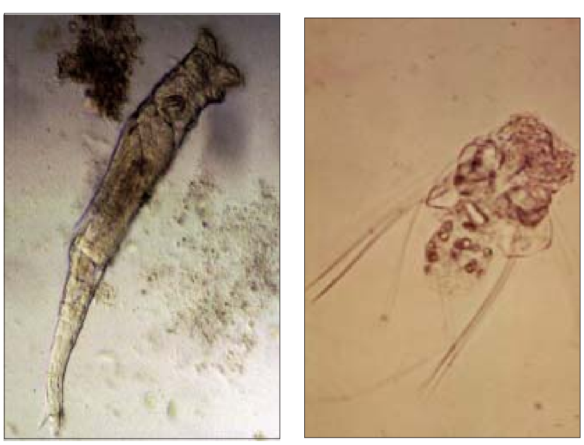


*Figure 6.24. Planktonic rotifers (*Philodina *sp., left;* Polyarthra *sp., right) found in Old Woman Creek estuary (David M. Klarer).*

PHYLUM NEMATODA

Nematodes, commonly known as roundworms because of their circular cross-section, are a diverse group of animals that can occur in great numbers within a small area. Three genera (*Tobrilus*, *Dorylaimus*, and *Criconemoides*) in 3 orders and in 3 families of the class Adenophorea have been identified in Old Woman Creek estuary. Nematodes are small invertebrates (generally less than 1 cm long) that occur in most benthic and epiphytic habitats in the estuary and at times they are very abundant. Roundworms totally lack cilia and flagella. They move by undulatory propulsion in which sinusoidal waves pass backwards along the body length. This strategy is particularly suitable for movement in a fluid medium. The genus *Tobrilus* feeds on small microfauna, including other nematodes; *Dorylaimus* is adapted for harvesting algae and other microflora; and *Criconemoides* is an ectoparasite that commonly attacks plant roots which in turn form galls that become feeding sites for others of their kind (Parker 1982).

PHYLUM MOLLUSCA

These soft-bodied animals, often with hard calcareous shells, include two familiar freshwater classes: Gastropoda (snails) and Bivalvia (clams). Their fleshy mantle secretes a shell which consists of a protein matrix reinforced by crystalline calcium carbonate in the form of either calcite or aragonite. Respiratory gills (ctenidia) are located in a posterior cavity formed by folds in the mantle.

Class Gastropoda. Snails possess a single shell (or valve) that is either flatly coiled or spiraled into a cone-like shape. In the estuary, the shells are typically drab-colored and range in size from a few millimeters for the small physids to over 50 mm for the Japanese mystery snail (*Cipangopaludina japonicus*). Part of the soft body protrudes from the shell aperture and bears a distinctive head with a pair of tentacles, often containing photosensitive eyes. Ten species of aquatic snails, in 2 orders and 5 families, have been identified in Old Woman Creek estuary, as well as one terrestrial species in the watershed. Most of the snails are benthic organisms that move slowly over the sediments of the estuary. Many feed on encrusted growths of algae, while others are detritivores or omnivores. Some burrow into the soft muds or detritus during dry periods or when habitats become frozen solid in winter. The land snail, *Mesodon thyroidus* in the family Polygyridae, prefers the humid woodlands surrounding the estuary. Members of this family live under dead wood, leaves, and stones. They mainly are active nocturnally or during rain, and feed primarily on mold and fungi (Parker 1982).

Class Bivalvia. Clams and mussels possess a two-piece shell, made up of 2 valves, thus the name "bivalve." The two opposing valves are connected by a hinge and are opened and closed with powerful muscles. Clam shells are commonly oval shaped, range in color from yellow to brown or green, and possess concentric, annular growth lines. Zebra and quagga mussels (*Dreissena polymorpha* and *Dreissena bugensis*), recent invaders of Lake Erie, have distinctive strips and litter the barrier beach at the estuary mouth. Unlike the snails, the protruding soft body parts of the bivalves lack head, eyes, and tentacles. Bivalves generally feed by filtering planktonic microorganisms out of the water, but some burrowing forms feed on organic matter strained from the substrate. Seven species of bivalves, in 2 orders and 3 families, have been found in Old Woman Creek estuary and an additional 15 species are in the adjacent nearshore waters and tributaries of Lake Erie. Four of the bivalves reported for the nearshore waters of Lake Erie in the vicinity of the Reserve are listed by the Ohio Division of Wildlife (1992) as threatened (T) or of special interest (S); no other invertebrates found within the study area appear on the State list:

Black sandshell (*Ligumia recta*) (T)
Fawnsfoot (*Truncilla donaciformis*) (T)
Deertoe (*Truncilla truncata*) (S)
Purple wartyback (*Cyclonaias tuberculata*) (S)

PHYLUM ANNELIDA

The most obvious trait of annelids is their body plan which consists of an elongated and segmented tube. Each segment is essentially the same and divided from the next segment by a ring-like marking. Two classes are found in the estuary, the leeches (Hirudinea) and aquatic and terrestrial earthworms (Oligochaeta).

Class Hirudinea. Leeches are flattened, segmented worms—often patterned and brightly colored. They possess both anterior (front) and posterior (rear) suckers, which are variously used for attachment, feeding, or locomotion. The leeches found in the estuary are either predators of other macroinvertebrates or temporary ectoparasites of fishes, amphibians, turtles, or water birds. Of the 4 species of leeches documented for the estuary, *Batracobdella phalera*, a fish parasite, is most common.

Class Oligochaeta. Aquatic earthworms are generally elongated, cylindrical worms that bear a few short bristles or hairs (chaeta) on each body segment. The silty bottom sediments and algal mats of the estuary have yielded 42 species of oligochaets in 2 orders and 4 families. Many are deposit feeders on the soft sediments of the estuary, utilizing the organic components for their nutrient source (Figure 6.25). Others feed primarily on periphyton or detritus, and a few are carnivorous, such as *Chaetogaster* spp.

*Figure 6.25. Oligochate worm (*Branchiura sowerbyi*) found in Old Woman Creek estuary sediments (Center for Lake Erie Area Research).*

PHYLUM ARTHROPODA

This phylum is the most successful in terms of numbers and diversity of terrestrial invertebrate animals and one of the most prominent freshwater taxa. Three of the classes are diverse and important components of the Old Woman Creek estuary and watershed: Arachnida (spiders and water mites); Crustacea (cladocerans, copepods, amphipods, and crayfishes); and Insecta (flies, bugs, and beetles). As a group, most members are characterized by a chitinous exoskeleton and ridged, jointed appendages which have been modified as legs, mouthparts, and antennae.

Class Arachnida

This class includes spiders, scorpions, ticks, and mites. In general, they are terrestrial arthropods that have their body divided into two main regions: (1) a cephalothorax (fused head and thorax) bearing 6 pair of appendages, of which 4 pairs are walking legs, and (2) an abdomen that bears no locomotive appendages. The 4 pair of walking legs and the absence of antennas serve as a simple way to distinguish arachnids from insects which have 3 pairs of walking legs and prominent antennas. The two arachnid orders that contain spiders and mites are represented in the watershed.

Order Araneae. In spiders the cephalothorax is covered by a carapace shield which usually contains 8 simple eyes. The abdomen generally has 3 pair of silk spinnerets. The proteinaceous fluid silk, which issues from these appendages, polymerizes under tension forming a hardened thread (Pearse et al. 1987). The tips of the spinnerets have a battery of minute spinning tubes that connect with several kinds of silk glands. The glands produce different types of silk for constructing various parts of a web, producing adhesive threads, making a protective cocoon, and binding the prey. All spiders spin silk, but relatively few species weave the spiraling orb webs (family Araneidae) found in the uplands surrounding the estuary. Within the Old Woman Creek watershed, 74 species of spiders, in 16 families, have been identified (Phillips 1998).

Order Acriformes. Mites differ from spiders in having their cephalothorax and abdomen fused into an unsegmented, ovoid body. Only members of the suborder Hydrachnida have become adapted to aquatic environments. Most water mites are brightly colored—commonly dark red, scarlet, or orange (Figure 6.26). They breathe air, but spend extended periods in the estuary on the mud bottoms and submerged plants searching for prey. Like spiders, water mites are carnivorous feeders, clutching their prey and sucking the body juice. Three genera of water mites have been identified in Old Woman Creek estuary.

Class Crustacea

Crustaceans have segmented bodies that are divided into head, thorax, and abdomen. They possess paired, joined appendages; and have an exoskeleton—a hard, durable, and protective body covering. The sclerotization of the covering (stiffening facilitated by chitinous plates) is interrupted at the joints which insures mobility. The exoskeleton is molted at intervals to permit growth of the individual. Nine orders of crustaceans are found in the Old Woman Creek study area, including cladocerans, ostracods, copepods (calanoids, harpacticoids, and cyclopoids), arguloids, isopods, amphipods, and decapods.

*Figure 6.26. Water mite (*Limnesia *sp.) found in Old Woman Creek estuary (Center for Lake Erie Area Research).*

Subclass Branchiopoda. Order Cladocera (water fleas) consist of small crustaceans, 0.2 to 3.0 mm in length, that swim in rapid jerks caused by the beating of branched second antennae. Cladocerans are the preferred food of many young and adult estuary fishes. They have a distinct head with vision organs, usually consisting of a compound eye and a smaller light sensitive eye or ocellus (Ruppert and Barnes 1994). The body is covered by a protective bivalve carapace. Complex movements of thoracic legs produce a constant current of water between the valves which facilitates the filtering of food particles, such as bacteria, algae, protozoans, and organic detritus from the water. In Old Woman Creek, its estuary, and the adjacent nearshore waters of Lake Erie, a total of 39 species, in 8 families, have been identified (Figure 6.27). Bur et al. (1986) reported the spiny water flea (*Bythotrephes cederstroemi*) as a recent invader to the Great Lakes (Figure 6.28).

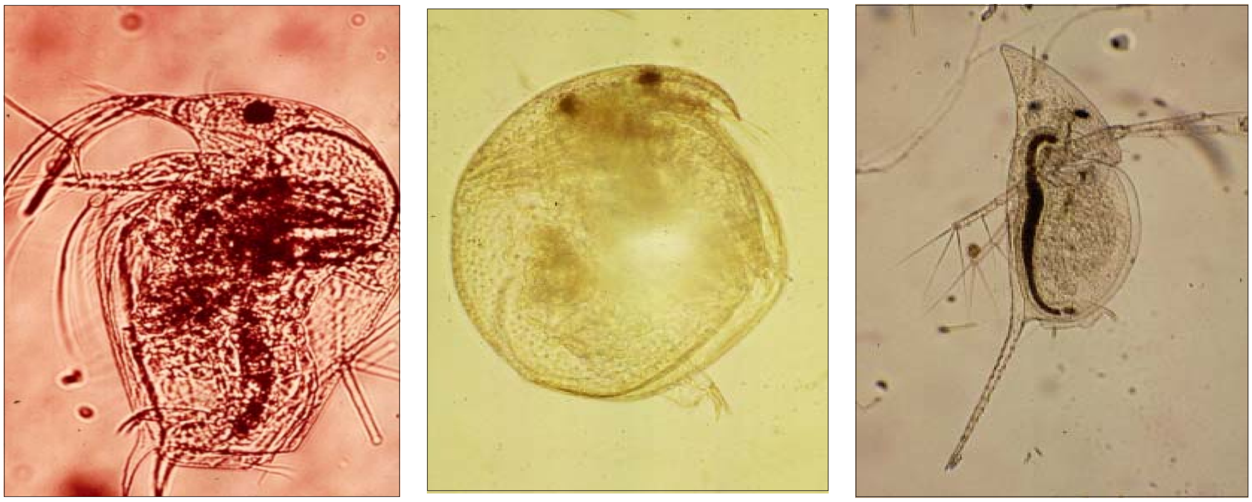


*Figure 6.27. Planktonic cladocerans (*Bosmina longirostris*, left;* Chydorus sphaericus*, center;* Daphnia retrocurva*, right) found in Old Woman Creek estuary (David M. Klarer).*

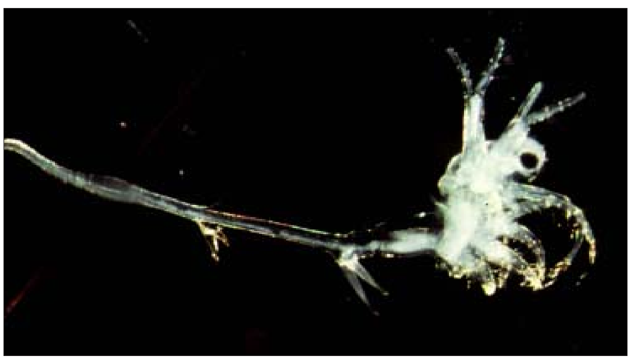


*Figure 6.28. Spiny water flea (*Bythotrephes cedarstroemi*) found in the nearshore waters of Lake Erie (Kenneth Krieger).*

Subclass Ostracoda. Commonly known as seed shrimp, these small crustaceans are distinguished by a bivalved carapace which envelops their soft body. They are typically herbivores or detritivores that live in benthic habitats. Nine species of ostracods, in 5 separate families, have been found in the estuary.

Subclass Copepoda. Copepods are another group of small crustaceans—subdivided into three orders: Calanoida, Harpacticoida, and Cyclopoida. Copepods have been estimated as the most numerous multicellular animal in the world (Pearse et al. 1987). They are voracious consumers of phytoplankton and small invertebrates and are in turn fed on by a variety of larger invertebrates and fishes. The copepod body is shrimp-like and ranges from 0.3 to 3.0 mm in length. They appear to glide rapidly and smoothly through the water by using thoracic appendages (calanoids) or the second antennae (cyclopoids). Harpacticoids tend to crawl over the bottom. Identification of the three orders is based mainly on morphological details of appendages and feeding habits. Calanoid copepods feed on plankton by filtration. Their second antennae are used as screws to produce a current from which phytoplankton is either filtered or seized by the mouth. Cyclopoid copepods (so named for a single eye spot in the front of the head) do not filter feed but use mandibles to capture a variety of small animals, including mosquito larvae (Figure 6.29). Harpacticoid copepods inhabit macrophytes and sediments, and feed by scraping organic matter from submerged surfaces. A total of 25 copepod species, in 4 families, have been reported from the estuary.

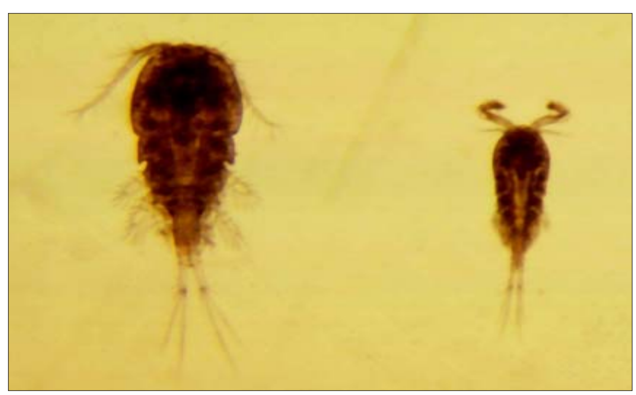


*Figure 6.29. Planktonic copepod (*Cyclops *sp.) from Old Woman Creek estuary (Kenneth Krieger).*

Subclass Branchiura. In the estuary, this subclass is represented by one genus, *Argulus*, in the order Arguloida. As the common name "fish lice" suggests, these small crustaceans are ectoparasites and attach themselves to the gills of fish. Their mandibles have been modified to form a pair of hooks and their maxillules have become large suckers. In *Argulus* the mandibles are incorporated into a specialized proboscis —a sheathed, hollow spine is used to pierce the skin of the host fish and extract body fluids (Thorp and Covich 1991).

Subclass Malacostraca. This subclass contains three important orders which are represented in Old Woman Creek estuary: Isopoda (aquatic sow bugs), Amphipoda (scuds), and Decapoda (crayfishes and shrimps). Isopods are dorsoventrally flattened and well adapted for crawling. As the name of the order implies, all their walking-leg appendages are similar in design. Most isopods are detritus feeders, such as *Caecidotea racovitzai*. Of the three orders, amphipods are more compressed laterally and tend to swim on their sides. Their first three pleopods (abdominal appendages) are modified as swimmerets. The two common amphipods in the estuary are *Gammarus fasciatus* and *Hyalella azteca*. Decapods are the largest arthropods in the estuary and are represented by two crayfishes (*Cambarus diogones* and *Orconectes rusticus*) and a glass shrimp (*Palaemonetes kadiakensis*).

Class Insecta

Insects, the largest class of invertebrates found in the Old Woman Creek watershed, consist of two subclasses: Entognatha (primitive insects represented by springtails and diplurans) and Ectognatha (true insects represented by 22 orders). Altogether, 758 taxa of insects have been identified from the study area.

Orders Collembola & Diplura. These two orders include the springtails and diplurans. As primitive insects, they are small, wingless, and usually blind. Springtails have an abdominal jumping organ and well-developed legs. Diplurans have a v-shaped tail formed by two caudal filaments at the end of their abdomen. These insects live in damp leaf humus, decomposing wood, and in soil beneath stones and fallen trees in the upland woodlots surrounding the estuary and throughout the watershed.

Order Thysanura. This order includes the silverfish. These fast-running insects have three narrow, elongated appendages at the end of the abdomen. Unlike the more primitive entognathan insects which occupy similar natural habitats, silverfish have compound eyes. These silver-gray insects can be domestic pests, feeding on the starch in books and textiles.

Order Ephemeroptera. This order includes the mayflies. These winged insects have medium-sized, elongated soft bodies with usually three long threadlike tails. Mayflies are unique insects in that a fully winged terrestrial life stage (subimago) precedes the sexually mature adult stage. The adult mouthparts are reduced and useless, thus they are short-lived as their "ephemeral" order name implies. Mayflies spend nearly all of their lives as nymphs in the waters of the creek, estuary, and lake. Aquatic nymphs of some 18 species have been found in the estuary, Old Woman Creek, and adjacent tributaries. The burrowing mayfly, *Hexagenia limbata*, has only two tails and is noteworthy because it emerges in enormous numbers from Lake Erie, piling up along the shore and in the streets of lakeside towns (Figure 6.30). Until the middle 1950s, this was a frequent happening along the shores of the lake, but environmental degradation in Lake Erie dramatically reduced the numbers of these insects for four decades. With improved Lake Erie water quality in the 1990s, mayflies have experienced a resurgence.

*Figure 6.30. Adult mayfly (*Hexagenia limbata*) after emerging from estuary sediments (Gene Wright).*

Order Odonata. This order includes the damselflies and dragonflies. Within the Old Woman Creek study area, 25 species of damselflies and 24 species of dragonflies have been identified. These relatively large, beautifully colored insects spend most of their time in flight. Their immature stages are aquatic (breathing by means of gills); the adults are most often found near water. Both nymphs and adults are predaceous on various other insects and invertebrates, but they are harmless to humans in that they neither bite nor sting. The gills of damselfly nymphs take the form of three leaflike structures at the end of the abdomen, while in dragonfly gills are internal within the rectum. Dragonfly nymphs draw in water through the anus, extract dissolved oxygen, and expel it through the same organ (Figure 6.31). To escape predation, they can expel water rapidly yielding a type of jet propulsion. Adults of both groups have four elongated, many-veined, and membranous wings and can be differentiated by the position of their wings while at rest—damselflies fold their wings close together vertically over their backs, while dragonflies hold their wings straight out horizontally from the body.

*Figure 6.31. Nymph darner dragonfly (*Aeshna *sp.) on aquatic vegetation (ODNR).*

Orders Blattaria and Mantodea. These orders include the cockroaches and mantids. Cockroaches are relatively large, flattened, oval-shaped, and fast-running insects with long hair-like antennae and numerous leg spines. Their head is concealed under a triangular shield (pronotum). They have an unpleasant odor and feed at night, hiding in crevices during the day. The Oriental cockroach (*Blatta orientalis*) and the American cockroach (*Periplaneta americana*) commonly invade houses within the watershed, while the small, wood cockroach (*Parcoblatta*) is more often found in woodlots under dead logs and stones.

Mantids are large, elongated, and slow-moving insects that are striking in appearance because their front legs are bent in an upraised or "praying" position. They are predaceous on a variety of insects, usually laying in wait for their prey in this attitude. They are colored a protective green and brown that makes them difficult to see in foliage. Although strong fliers, they are rarely observed on the wing. The Chinese mantid or praying mantis (*Tenodera aridifolia sinensis*), now relatively common in the watershed, was introduced to the United States near Philadelphia about 100 years ago (Borror and DeLong 1971).

Order Isoptera. This order includes the termites. These social insects, sometimes called white ants, live in colonies having a caste system which includes reproductive males and females, sterile workers, and sterile soldiers. Termites are destructive, feeding entirely on wood. The wood particles are then digested by protozoan living in the termite's gut. The eastern subterranean termite (*Reticulitermes flavipes*) is found in the watershed. This termite eats the soft spring growth of wood, hollowing out the sapwood along the length of the grain and leaving only brown specks of excrement behind. As they consume living trees or wood buildings, they maintain contact with the ground by means of earthen tubes that connect the feeding galleries with the ground (Swan and Papp 1972).

Order Orthoptera. This order includes the grasshoppers, katydids, and crickets. These insects are noted for their powerful hind legs, which are adapted for jumping by greatly enlarged third segments (femora). They usually have two pair of long, narrow, many-veined wings. Crickets and katydids produce a characteristic sound, or song, by rubbing specialized parts of their forewings together, in contrast to band-winged grasshoppers which snap hind wings in flight. Males generally do the singing; songs mainly function to attract females for mating. Most members of this order are plant feeders; some are very destructive to cultivated plants. Within the watershed, 6 grasshopper, 2 katydid, and 7 cricket species have been identified.

Order Dermaptera. This order is represented by at least 3 species of earwigs in the watershed. These are medium-sized insects, typically brown in color, with short leathery forewings and long membranous hindwings that fold straight back under the front pair. Some species are wingless, such as the ring-legged earwig (*Euborellia annulipes*) which occasionally invades dwellings feeding on foodstuffs and house plants. A distinctive feature of earwigs is a pair of curved, pincer-like cerci at the hind end of insect that are used in defense, such as grasping an attacking ant. The wings of the European earwig (*Forficula auricularia*) are not strong enough for this insect to take off from the ground or for sustained flight— they can only fly by taking off from a high place.

Order Plecoptera. This order includes the stoneflies. The common name of these insects reflects the fact that they spend most of their life as nymphs (2-3 years) crawling among stones in streams, and as adults (15-20 days) resting on rocks near the water. They are poor fliers and are seldom found far from water. Stonefly nymphs are similar in appearance to mayfly nymphs, except that they only have two tail filaments. Because stonefly nymphs lack extensive gills, in many species obtaining oxygen by diffusion through the body cuticle, they occur only in oxygen-rich water. Thus, the presence of stonefly nymphs in a stream is an indicator of good water quality conditions. The green-winged stonefly (*Isoperla duplicata*) feeds on the pollen of foliage along the banks of Old Woman Creek. Most of the 14 stonefly species identified for the study are were found in Old Woman Creek upstream of the estuary or in nearby Mill Hollow on the Vermilion River.

Order Thysanoptera. This order includes the thrips. They are mostly small, inconspicuous insects with two pairs of wings fringed with eyelash-like hairs. Although small, their bodies are well armored (sclerotized) and solid brown, black, or yellow in color. They can be found in most blossoms and feed by sucking juices from plants. A common thrips (family Thripidae), a three-tailed thrips (family Phlaeothripidae), and a banded thrips (family Aeolothripidae) have been observed in the watershed.

Order Hemiptera. This order includes the true bugs. These insects have widely differing sizes, shapes and habits. Their wings are usually thickened at the base and membranous at the tip. The main unifying characteristic of this order is the structure of the piercing-sucking beak (rostrum) and mouthparts, common to all members. During piercing, the rostrum, richly supplied with organs of smell and touch, does not enter the tissue of the food organism, but guides a bundle of hollow, barbed stylets to a favorable spot for the bite. Juices are most often sucked from the sieve tubes in the vascular bundles of plants. The order contains aquatic bugs such as water scorpions (*Nepa* and *Ranata*), giant water bugs (*Belostoma*), water boatmen (*Trichocorixa*), backswimmers (*Notonecta*), and water striders (*Gerris*), as well as diverse terrestrial bugs including lace bugs (*Corythuca*), plant bugs (*Lygus*), assassin bugs (*Sinea*), seed bugs (*Lygaeus*), and stink bugs (family Pentatomidae)—all of which have representatives in the study area. Unlike their land-based, plant eating counterparts, many water bugs attack any animal they can manage, large or small, including small fish. Altogether, 78 species of bugs in 27 families have been identified in the vicinity of Old Woman Creek.

Order Homoptera. This order includes the cicadas, leafhoppers, and aphids. These insects are closely related to the true bugs, except the wings of homopterans are similar along their length and not divided into a thick strong base and a fragile tip, as they are in the order Hemiptera. All homopterans are terrestrial and vegetarians; most of them suck the juices from vascular plants. Many members of this order are serious pests of cultivated plants, causing damage by feeding and by serving as vectors of plant diseases. Common representatives in the study area include spittlebugs (*Philaenus*), cicadas (*Tibicen*), leafhoppers (*Graphocephala*), and aphids (*Aphis*). A total of 32 species of homopterans in 10 families have been found in the watershed.

Order Neuroptera. This order includes the nerve-wing insects, such as dobsonflies, alderflies, and lacewings. Members of this order have many veins in their delicate wings. The nymphs of dobsonflies (*Corydalus*) are aquatic; known as hellgrammites, they are extremely predacious and cannibalistic during this 2-to-3-year phase in steams such as Old Woman Creek.

The larvae of the spongillafly (*Climacia*) are parasitic on and live in the cavities of freshwater sponges. The larvae move onto land in summer where they weave a cocoon, covered with hexagonal meshed net, on vertical objects near the shore. Here transformation to a pupa takes place before they emerge as flying adults. The green lacewing known as golden eye (*Chrysopa oculata*) appears in autumn in the watershed as a greenish shimmering insect with sparkling gold eyes and transparent wings that look as fragile as glass. Within the watershed, 11 species of neuropterans in 6 families have been identified.

Order Coleoptera. This order includes the beetles and weevils. The extraordinary variety in their forms has made the beetles the insect order with by far the greatest number of species. In Old Woman Creek watershed 179 species of beetles in 39 families have been reported. This is a small number, however, compared with the nearly 350,000 species of beetles that have been described world wide. The name of the order means sheathed wings, referring to the hardened forewings that cover the membranous hindwings. Most beetles are herbivorous, but some families that live in Old Woman Creek and the estuary are hunters, such as the predaceous diving beetles (*Dytiscus* and *Laccophilus*), while other water beetles are scavengers (*Berosus* and *Hydrophilus*). Whirligig beetles (*Dineutes*) often form large aggregations in protected open waters of the estuary (Figure 6.32). Most of the beetle families are terrestrial and have the ability to fly, but most often only to reach low vegetation. Land beetles eat leaves, bark, dung, and some textiles. The larvae, called grubs, can be either predacious or vegetarian. Although some species attack plants and food stores, others eat plant pests and pollinate flowers.

Orders Mecoptera and Siphonaptera. These orders include the scorpionflies and fleas. The slender bodies of scorpionflies are amber-colored with dark spots or bands on their four membranous wings. The common name for these insects is derived from the male genitalia which looks like the upward curved sting organ of a scorpion. The common scorpionfly, *Panorpa helena*, occurs in the watershed and inhabits woods and ravines with dense vegetation. They feed chiefly on dead or injured insects.

*Figure 6.32. Gyrating mass of whirligig beetles (*Dineutus *sp.) in an embayment of Old Woman Creek estuary (Charles E. Herdendorf).*

Fleas are small wingless insects that feed on the blood of mammals and to a lesser extent that of birds. The genus *Ctenocephalides* includes the cat flea (*C. felis*) and the dog flea (*C. canis*)—common pests of cats and dogs in the watershed and in buildings where these domestic animals are kept. The dog flea serves as the intermediate host of the dog tapeworm (*Dipylidium caninum*).

Order Diptera. This order includes the true flies. Common in all habitats, flies are easily distinguished from other insects because they have only one pair of complete wings. Most flies have large compound eyes and mouthparts that are modified for piercing, lapping, or sucking. The larvae (maggots) of many species are soft, legless, headless, and often white. The aquatic larvae of mosquitoes (*Aedes* and *Culex*), midges (*Chironomus* and *Procladius*), and crane flies (*Tipula*), all found in the estuary, are slender and have distinct heads. Many of the chironomid larvae are blood red in color (Figure 6.33). These "bloodworms" have hemoglobin in their circulatory system that allows them to store oxygen and survive at near anoxic conditions. A total of 127 species of flies, in 38 families, have been identified within the study area, 54 species of which are in the midge family (Chironomidae).

*Figure 6.33. Chironomid larvae (*Chironomus *sp.), a major component of the Old Woman Creek benthos (ODNR).*

Order Trichoptera. This order includes the caddisflies. Trichopterans are an advanced order of insects, closely related to the order Lepidoptera (butterflies and moths), but adapted for aquatic life in the immature stages. Adult caddisflies are similar to moths except their wings usually possess hairs rather than the scales typical of moth wings. Caddisflies are usually brownish, inconspicuous, small, and moth-like; they are most active at night. Like mayflies, the adults have reduced mouthparts and seldom, if ever, eat. The head and thorax of the aquatic larvae are sclerotized and pigmented; the abdomen is soft and colored light brown to brilliant green. Their 3 pair of legs are prominent and directed forward. Many larvae construct portable cases of various natural objects, such as grains of sand and gravel, leaves, or twigs, which are fastened together with a glue-like substance or with silk. Larval cases vary considerably, both in shape and materials employed, but each species makes a characteristic type of case, such as tube-makers (*Polycentropus*), log-cabin makers (*Limnephilus*), and sailcase makers (*Helicopsyche*). Larvae of some species construct silken nets (*Hydropsyche*) and feed on material caught in the nets. Most larvae feed on plant material, but a few non-case makers (*Rhyacophila* and *Phryganea*) are predaceous. Within the estuary and adjacent streams tributary to Lake Erie, a total of 74 species of caddisflies, in 9 families, have been identified.

Order Lepidoptera. This order includes the butterflies and moths. As noted earlier, these insects have 4 large membranous wings that are covered with scales. When handled some of these scales easily rub off. Moths and butterflies are separated on the basis of certain head structures; individual families are further divided on the basis of wing venation. Moths have threadlike or plumose antennae and a bristle (frenulum) at the front base of the hind wing, whereas butterflies have knobbed antennae and lack a frenulum. Lepidopterans feed principally on nectar and other liquid foods, and are commonly associated with flowers. Their flight is somewhat erratic, but relatively fast. A few butterflies, such as the monarch (*Danaus plexippus*), migrate great distances. The larvae of this particular species feeds on milkweed. Lepidopteran larvae, commonly called caterpillars, are cylindrical in shape with well-developed heads, 3 pair of thorax legs, and 5 pair of abdominal prolegs. Many larvae pupate in silken cocoons. A total of 83 moth and butterfly taxa, including one aquatic taxa, have been reported in the watershed.

Order Hymenoptera. This order includes the ants, bees, and wasps. From a human standpoint, this order is regarded as the most beneficial of all the insects, for it contains food producers (honeybees), plant pollinators, and parasites or predators of various insect pests. The insects in this order also exhibit a great diversity of habits and complexity of behavior culminating in elaborate social organizations. The winged members have four membranous wings, with the hindwing smaller than the forewing. In flight, a tiny set of hooks are employed to attach the two sets of wings together. Ants, bees, and wasps have a constricted "waist" or pedicel between the thorax and the abdomen, whereas sawflies and horntails (*Tremex*) do not. Larvae have well-developed heads and mouthparts, but are legless except for sawflies. Most species are solitary, but ants and some bees and wasps have a complex social organization with sterile workers. Investigators have identified 52 species of hymenopterans, in 21 families, within the Old Woman Creek watershed.

Phylum Tardigrada

Tartigrades, or water bears, are near microscopic animals that live in the film of water surrounding mosses, algae, and rooted aquatic plants. The body has a somewhat bear-like appearance and consists of a distinct head and trunk with four pairs of leg-like projections, each bearing four claws. They crawl over vegetation, using their claws to grasp, while they feed on algal filaments and plant leaflets by sucking out cellular fluids. The tardigrades collected in the estuary belong to the family Macrobiotidae.

Phylum Bryozoa

Bryozoans are aquatic animals that occur in colonies. The individual animals (zooids) grow in a non-living case. They have a unique tentacular food-collecting organ called the lophophore. In the estuary, *Pectinatella magnifica* creates massive gelatinous colonies (Figure 6.34), *Plumatella casmiana* forms more honeycomb masses, *Lophopodella carteri* is found in small sac-like masses, and *Plumatella repens* occurs in branching and threadlike colonies. Called "moss animals," bryozoan colonies often look like mossy masses on lily pads or encrustation on floating twigs and branches. When the colonies disintegrate in the fall, most species produce a large number of oval winter buds (statoblasts). Similar to the gemmules of a sponge, individuals produced from these buds form new colonies in the spring.

*Figure 6.34. Bryozoan colony (*Pectinatella magnifica*) on an American lotus (*Nelumbo lutea*) leaf pad in the main basin in Old Woman Creek estuary (Gene Wright).*

Vertebrate Fauna

Vertebrates are all members of the animal phylum Chordata, subphylum Vertebrata. Of the seven classes in this subphylum, six are found in Old Woman Creek watershed and the adjacent region of Lake Erie: Agnatha (jawless fish), Osteichthyes (bony fish), Amphibia, Reptilia, Aves (birds), and Mammalia; only the class Chondrichthyes (cartilaginous fish – sharks and relatives) is absent. Members of this phylum possess the following characteristic features, at least during some stage of development: (1) a notochord (whence the name of the phylum is derived), a stout yet flexible rod-like structure running down the back of the trunk in the position occupied by the backbone in typical adult vertebrates, (2) a hollow dorsal nerve cord lying above the notochord, and (3) numerous gill slits, which open outward from the pharynx to the exterior (Gray 1970). The notochord is prominent in the embryo in every vertebrate, but in the adult it is supplanted by the backbone—vertebral column to which the group owes its name.

The diversity of habitats present within the Reserve and Old Woman Creek watershed contribute to a variety of plant and animal communities, each comprised of a distinctive fauna. A total of 121 fish, 27 amphibian, 25 reptilian, 52 mammalian, and 370 avian species have been identified in the Reserve, watershed, and adjacent tributaries and waters of Lake Erie; over half of these taxa are found within the boundaries of the Research Reserve (Appendixes D, E, and F). A detailed treatment of the vertebrate animals reported from the Old Woman Creek watershed is presented in Old Woman Creek SNP & NERR Technical Report No. 11, *Catalogue of the Vertebrate Fauna in Old Woman Creek Estuary, Watershed, and Environs* (Herdendorf et al. 1999b,2001d).

Fish

Within the Old Woman Creek estuary and watershed, 51 different fish species, in 2 classes, have been identified by Ohio Division of Wildlife (1974, 1980), Thibault (1984,1985), Hoffman (1985), Rotenberry et al. (1987,1989), Thoma (1999), Johnson (1994), and Jude (1996). Of the 51 species, 49 are reported from the estuary and 11 from the creek proper (Appendix D). None of the 23 fish species considered endangered, threatened, or of special concern found in north central Ohio have been reported from the waters of Old Woman Creek (Ohio Division of Wildlife, 1992; amended 1996). An additional 70 fish species in the adjacent tributaries and waters of Lake Erie (Trautman 1957,1981b; Tomelleri 1997).

Class Agnatha

This class includes the lampreys, the most lowly of vertebrates. These serpentiform fishes resemble eels superficially, but eels are highly developed bony fishes. In contrast, lampreys have no bones, no trace of paired fins, nor the biting jaw which is one of the most significant structural features of all other vertebrates. Two species of lamprey have been collected by Trautman (1981b) in Lake Erie off the mouth of the estuary (see Appendix D). To prey on other fish, lampreys, have developed an adhesive disk on a round mouth to attach to the prey and a protrusible rasping tongue-like organ.

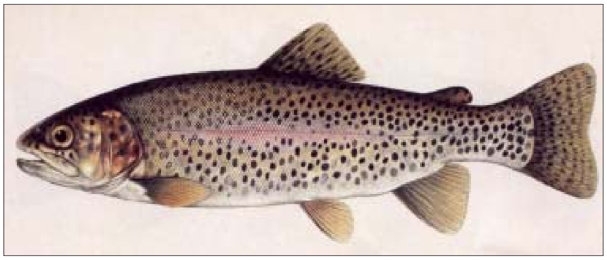
Class Osteichthyes

This class consists of the bony fishes—an ancient group appearing in the Devonian Period (350 million YBP) which rapidly assumed a dominant position in freshwaters. Diagnostic characteristics include: (1) jaws, (2) bony vertebrae, (3) paired fins, (4) paired nostrils, (5) commonly scaled body, and (6) usually a swim bladder. A total 119 species of bony fishes have been reported for the Old Woman Creek, adjoining watersheds, and the adjacent waters of Lake Erie (Figures 6.35 to 6.37 and Appendix D).

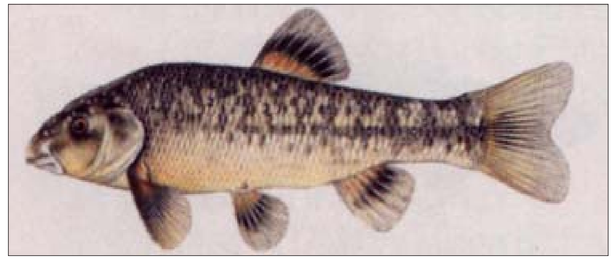
Amphibians and Reptiles

Class Amphibia

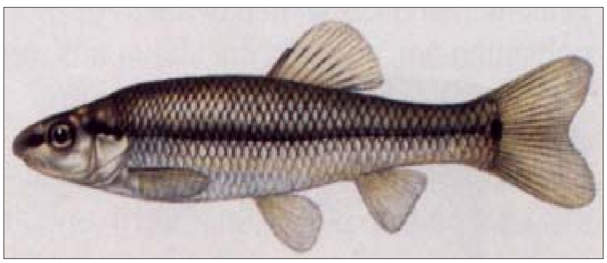
Amphibians constitute a class of vertebrate animals that include salamanders, toads, and frogs. These animals are characterized by: (1) moist glandular skin without scales, (2) toes that are devoid of claws, and (3) a larval stage that is usually aquatic. Most amphibians have four limbs that have evolved from ancestral lobe-fined fishes. All amphibians have gills during their early development stage, and while some retain them in adulthood, many others evolve lungs. Amphibians were the first vertebrates to cope with the rigors of life on land. Limbs and lungs are adaptations for a terrestrial existence, but amphibians remain vulnerable to dehydration and are still strongly linked to aquatic environments.



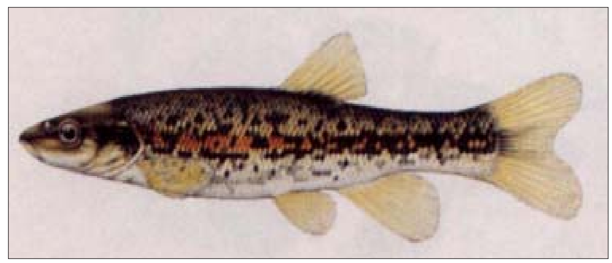
Rainbow [Steelhead] trout (*Oncorhynchus mykiss*)



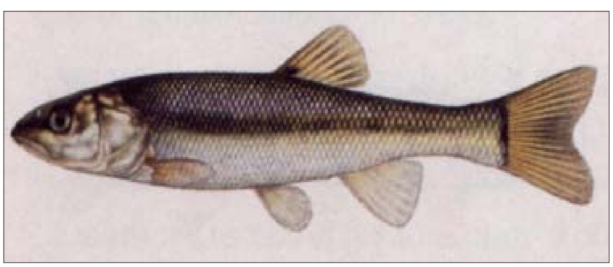
Stoneroller minnow (*Campostoma anomalum*)



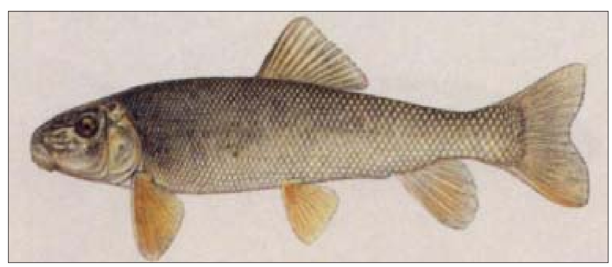
Bluntnose minnow (*Pimehales notatus*)



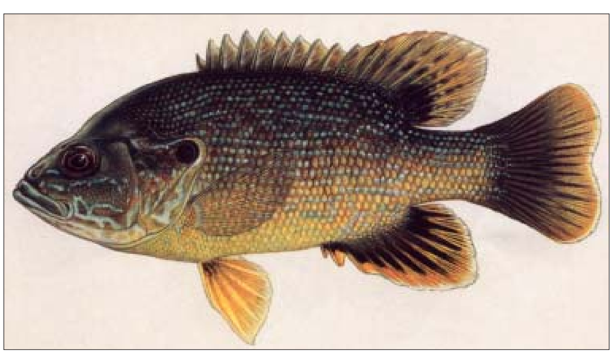
Blacknose dace (*Rhinichthys atratulus*)



Northern creek chub (*Semotilus atromaculatus*)



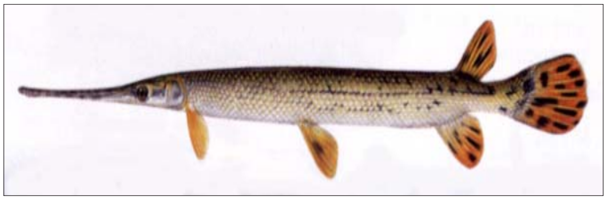
White sucker (*Catostomus commersoni*)



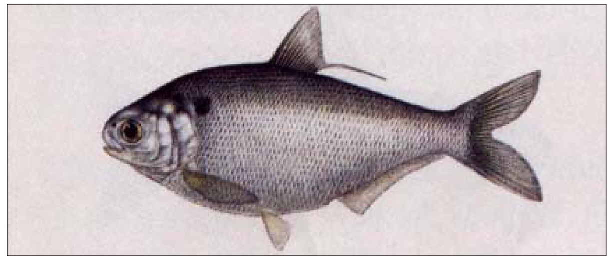
Green sunfish (*Lepomis cyanellus*)

Rainbow darter (*Etheostoma caeruleum*)

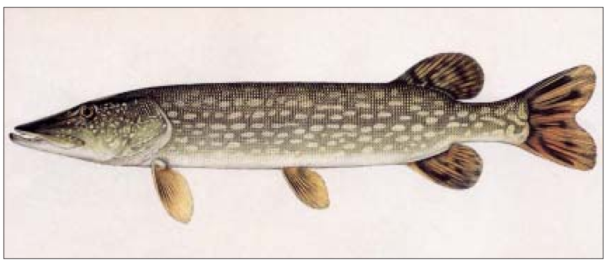
Figure 6.35. Representative fishes of Old Woman Creek (ODNR, artist: Joseph Tomelleri).



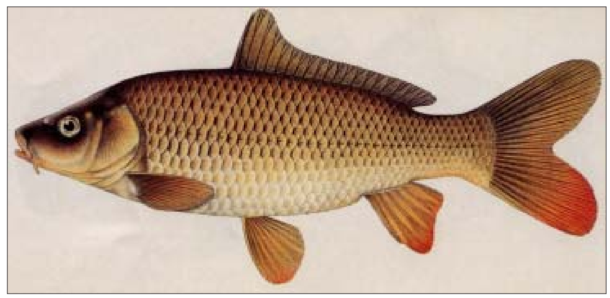
Longnose gar (*Lepisosteus osseus*)



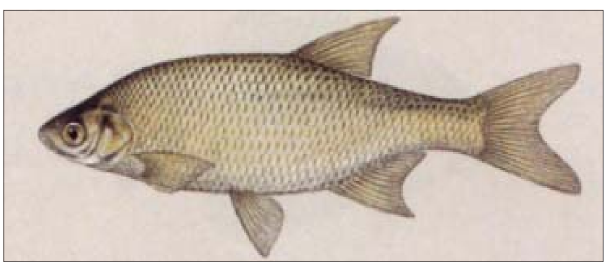
Gizzard shad (*Dorosoma cepedianum*)



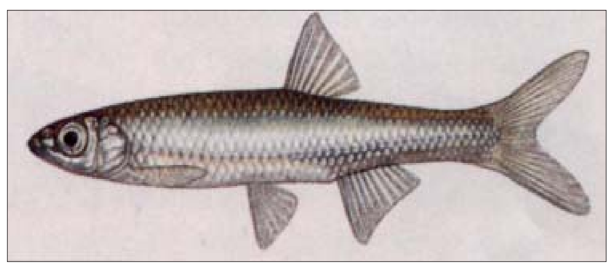
Northern pike (*Esox lucius)*



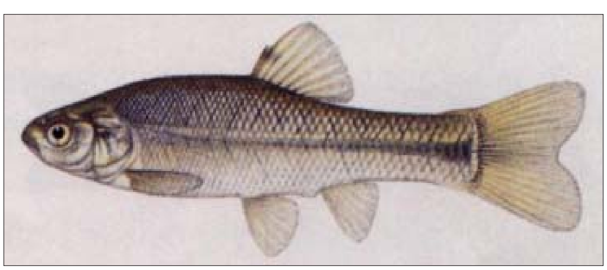
Common carp (*Cyprinus carpio*)



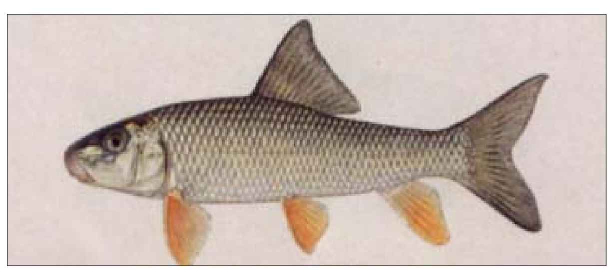
Golden shiner (*Notemigonus crysoleucas*)



Emerald shiner (*Notropis atherinoides*)



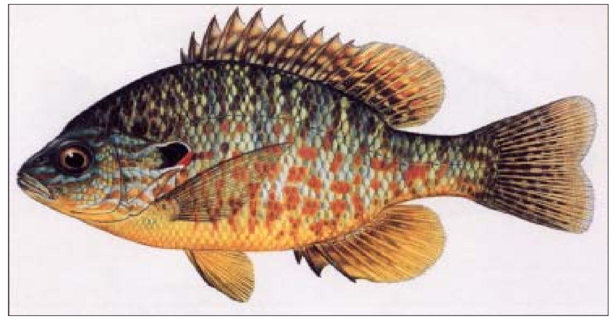
Fathead minnow (*Pimephales promelas*)



Golden redhorse (*Moxostoma erythrurum*)

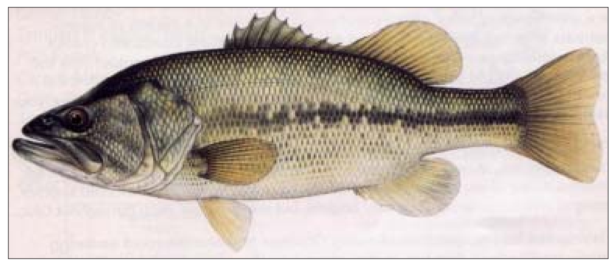
Figure 6.36. Representative fishes of Old Woman Creek estuary (ODNR, artist: Joseph Tomelleri).

Brown Bullhead (*Ameiurus nebulosus*)

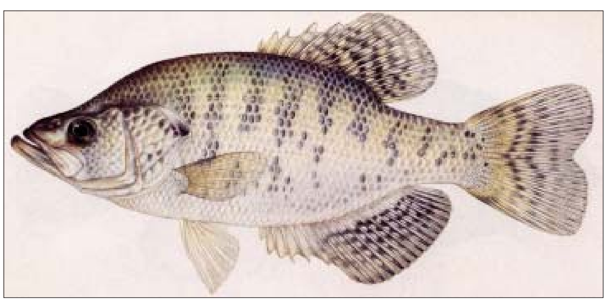


Pumpkinseed (*Lepomis gibbosus*)

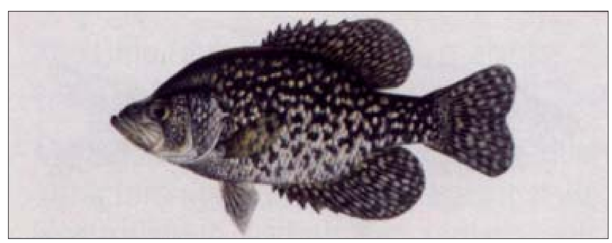
Bluegill sunfish (*Lepomis macrochirus*)



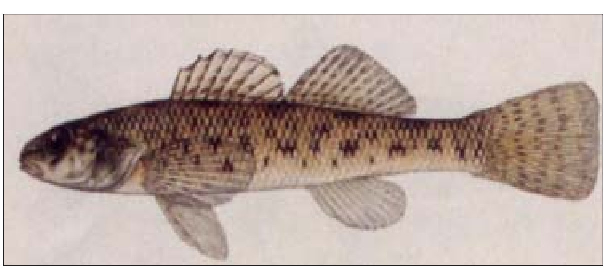
Largemouth bass (*Micropterus salmoides*)



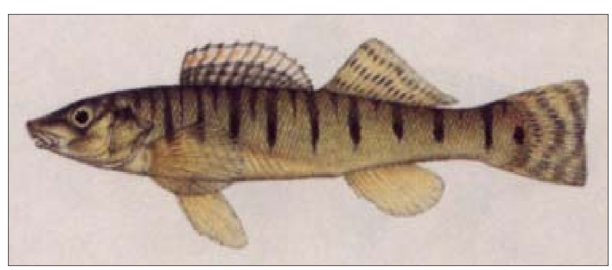
White crappie (*Pomoxis annularis*)



Black crappie (*Pomoxis nigromaculatus*)

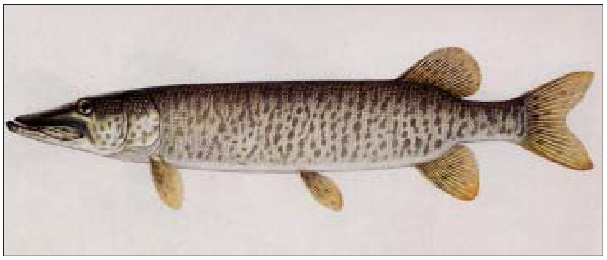


Johnny darter (*Etheostoma nigrum)*

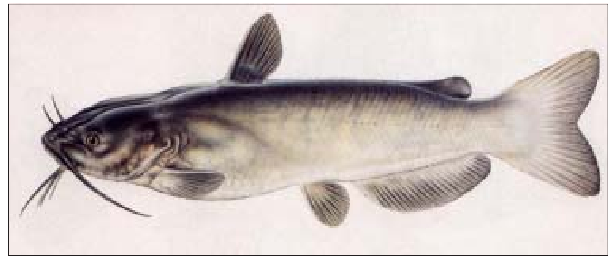


Logperch darter (*Percina caprodes*)

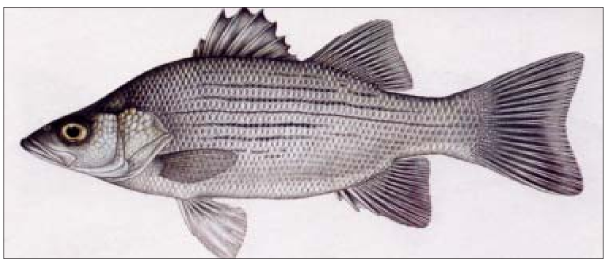
Figure 6.36 (cont'd). Representative fishes of Old Woman Creek estuary (ODNR, artist: Joseph Tomelleri).



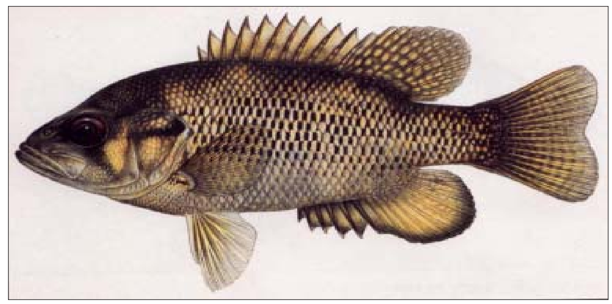
Muskellunge (*Esox masquinongy*)



Channel catfish (*Ictalurus punctatus*)

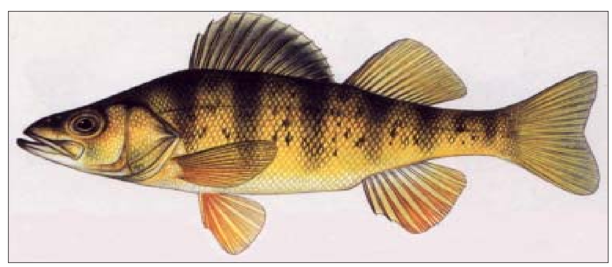


White bass (*Morone chrysops*)

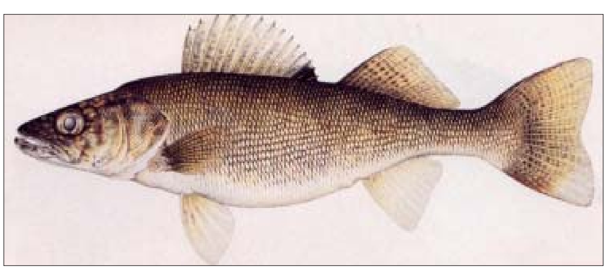


Rock bass (*Lepomis macrochirus*)

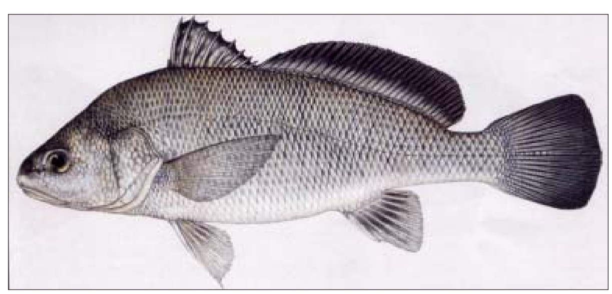
Smallmouth bass (*Lepomis macrochirus*)



Yellow perch (*Perca flavescens*)



Walleye (*Sander vitreus vitreus*)



Freshwater drum (*Aplodinotus grunniens*)

Figure 6.37. Representative fishes of nearshore Lake Erie (ODNR, artist: Joseph Tomelleri).

Most amphibians lay their eggs in water; the fish-shaped larvae have gills and tail-fins (Morgan 1930). Amphibian eggs which are deposited in sites exposed to sunlight have a dark pigment (melanin) over the upper hemisphere; whereas eggs deposited in concealed sites out of the light, lack the pigment. The occurrence of melanin may function to protect the embryo from ultraviolet radiation and to increase the temperature of the egg, through the greater heat absorption of a black or dark brown surface (Duellman and Trueb 1994, Stebbins and Cohen 1995). The black upper surface and the white lower surface may provide countershading, as found in many fish species, which makes floating eggs less detectable to predators when viewed from above the surface or from the bottom of the pool.

This class is represented by 16 species of salamanders, toads, and frogs in the Old Woman Creek watershed and adjacent waters of Lake Erie (Bernhardt 1985); an additional 11 species have been reported in nearby watersheds (Appendix F). The salamanders found in the study area are of three types [families]: (1) giant salamanders of which the aquatic and continually-larval mudpuppy is a member, (2) mole salamanders of which both the underground spotted salamander and a hybrid form (Figure 6.38) are resident, and (3) the lungless salamanders of which four subtypes [genera] are present: (a) dusky, (b) brook [two-lined], (c) woodland [redback, slimy, and ravine], and (d) red salamanders. The toads and frogs in the study area are also of three types [families]: (1) dry, warty skinned toads of which American and Fowler's toads are members, (2) chorus frogs of which the spring peeper and western chorus frog are abundant, and (3) true frogs of which the bullfrog, green frog, and leopard frog (Figure 6.39) are present.

*Figure 6.38. Silvery salamamder (*Ambystoma platineum*), a hybrid species common in the watershed (Glen Bernhardt).*

*Figure 6.39. Leopard frog (*Rana pipens*), one of the most abundant frogs in Lake Erie coastal wetlands (Glen Bernhardt).*

The Family Ambystomatidae (mole salamanders) is the only poorly represented family in the fauna of Old Woman Creek with only 2 of 7 regional species reported. The only amphibian listed as a species of special concern by the Ohio Division of Wildlife (1992; amended 1996), *Hemidactylium scutatum* (4-toed salamander) has not yet been found in the Old Woman Creek watershed.

Class Reptilia

Reptiles form a class of vertebrates that (1) are clad in scales or plates, (2) possess toes with claws, and (3) produce young that are miniature replicas of the parents. This class is represented by 19 species of turtles and snakes in the Old Woman Creek watershed and adjacent waters of Lake Erie; an additional 6 species have been reported in nearby watersheds (Appendix F). The turtles found in the study area are of four types [families]: (1) musk turtles, (2) snapping turtles, (3) box/water turtles, of which five subtypes [genera] (painted, spotted, Blanding's, map, and box turtles) are present, and 4) softshell turtles (Figures 6.40 and 6.41).

The snakes in the study area all belong to the colubrid family or harmless snakes, the largest snake family in the world. They vary in form and size from 2-m black rat and blue racer snakes to tiny brown snakes. Colubrid heads are as wide or wider than the neck with large and regularly arranged scales. Most members of this family have solid teeth on both jaws and well-developed eyes. Subtypes [genera] found in Old Woman Creek watershed include: racers, ringneck, rat (black rat and fox), milk, water (Figure 6.42), queen,

*Figure 6.40. Eastern box turtle (*Terrapene carolina*), a terrestrial turtle shown here on the Berea Escarpment (Charles E. Herdendorf).*

*Figure 6.41. Young spiny softshell turtle (*Apalone spiniferus*), a predominately aquatic turtle of the creek and estuary (Glen Bernhardt).*

brown (northern and midland), and garter (Butler's and eastern) snakes. The eastern fox snake (Figure 6.43) has been observed in trees overhanging the estuary.

The reptiles of the watershed are primarily known through the work of Bernhardt (1985). The algal species *Haematococcus pluvialis* has been reported by the authors only from the shell of the *Chelydra serpentina* (snapping turtle). Four of the six reptiles listed as species of concern by the Ohio Division of Wildlife (1992; amended 1996) have been reported from the Old Woman Creek watershed.

*Figure 6.42. Northern water snake (*Nerodia sipedon sipedon*), resting on a fallen tree at the edge of the estuary (Glen Bernhardt).*

*Figure 6.43. Eastern fox snake (*Elapha vulpina gloydi*), a resident of the estuary shore and uplands (Glen Bernhardt).*

BIRDS AND MAMMALS

Class Aves

This class forms a very distinct vertebrate group, characterized by a series of special features, most of which are adapted for flight and life in the air. Birds are bipedal for terrestrial locomotion, the front limbs being transformed into wings containing the rudiments of three fingers. The body is compact with an oversized breastbone (sternum) for the attachment of wing muscles. The skull, and the remainder of the skeleton, is lightly built, teeth are absent, and the tail bone is reduced. A high body temperature is maintained (38 to 44˚ C), commensurate with the need for continuous activity during flight. Feathers, the most prominent avian feature, are believed to be derived from horny reptilian scales (Gray 1970); these insulate the body and form lift-producing surfaces over the wings and tail. Birds have highly varied plumage and habits but, except for the Ratitae (birds with only rudimentary wings and no keel to the breastbone—such as the ostrich or kiwi), are built on a uniform structural pattern. The skin of birds differs from that of mammals in being thin, loose, and dry; there are no sweat glands—the only skin gland is the preen (uropygial) gland at the base of the tail (Young 1962). Feathers are cleaned with the beak, using oil obtained from this gland which is especially well developed in aquatic birds.

A total of 370 bird species have been reported in the region surrounding Old Woman Creek (Appendix E). Of this number all but 45 have been observed within the watershed. Virtually all of the 45 species not in the watershed were sightings of birds that were well away from their home range, such as the *Gavia pacifica* (Pacific loon) or the *Plegadis chihi* (white-faced ibis). Of the 44 species that are listed as species of concern by the Ohio Division of Wildlife, all but one species, *Chondestes grammacus* (lark sparrow), have been sighted in the Old Woman Creek watershed. One hundred and twenty five of the species are considered to be migratory and are passing through the region only to travel to and from their breeding and/or wintering grounds. Members of the local Audubon Society, Firelands Chapter assisted in compiling the list of birds in the Old Woman Creek watershed. Waterfowl (Figure 6.44), wading birds (6.45), and kingfishers (Figure 6.46) are the most common avian groups utilizing the estuary.

Bald Eagles. The bald eagle (*Haliaeetus leucocephalus*) is the national symbol of the United States and is listed as an endangered species by the State of Ohio (Ohio Division of Wildlife 1996). Two hundred years ago, when the first settlers arrived in northern Ohio, bald eagles were common along Lake Erie and in the coastal marshes and estuaries. As natural areas were converted to farms, harbors, and cities, the number of eagles declined. By 1975, only 4 active eagle nests remained in Ohio, all were along the shore of western Lake Erie. With the decreased use of many pesticides and the establishment of coastal preserves in recent decades, eagle numbers have increased to over 100 nests in 2004. In the past decade the bald eagle has become a relatively common raptor at the Reserve. During the winter months, as many as 14 individuals have been observed at one time roosting at the southern edge of the estuary and fishing in the nearshore waters of Lake Erie (Wright et al. 1997). Bald eagles are daytime feeders that primarily eat fish, but also consume waterfowl, small mammals, and carrion.

Mature bald eagles are easily identified by their large size, dark brown body, and conspicuous white head and tail (Figure 6.47). Immature eagles are a mottled brownish-gray color and acquire their white feathers at 3 to 5 years of age. Life expectancy in eagles is 15 to 20 years. The sexes are alike in appearance—females with an average weight of 5.4 kg are slightly larger than the males at 4.5 kg. An adult bird is about 80 cm long and has a wingspread of nearly 200 cm. Bald eagles are monogamous; the pair starts building a nest in December or January and nesting begins in February or March. The nest (sometimes called an eyrie) is usually located high in the fork of a large tree, often near a body of water. Many times the pair will simply add new branches, twigs, and grass to an existing nest (or even take over a great blue heron's nest) rather than build a new nest each year. In this way huge nests can be constructed, such as the "Great Nest" once located several kilometers to the east of the Reserve at Vermilion. This nest, the largest recorded in North America (Peterjohn 1989), was used from the 1891 to 1925 by several pairs of eagles until it fell 25 m to the ground during a storm. The nest measured nearly 4 m across by 2.5 m high, and weighed almost 2 tons.

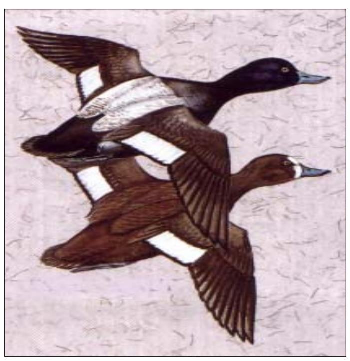
A clutch usually consists of 2 dull white eggs, sometimes 1, and rarely 3. The incubation period is about 35 days, with both the female and male taking

American black duck (*Anas rubripes*)

Blue-winged teal (*Anas discors*)

Bufflehead (*Bucephala albeola*)

Goldeneye (*Bucephala clangula)*



Lesser scaup (*Aythya affinis*)

Mallard (*Anas platyrhynchos*)

Ruddy duck (*Oxyura jamaicensis*)

Wood duck (*Aiix sponsa*)

Figure 6.44. Representative waterfowl of Old Woman Creek estuary (Ducks Unlimited Canada).

*Figure 6.45. Great blue heron (*Ardea herodias*), a common wading bird of the estuary (Cornell Laboratory of Ornithology).*

turns incubating the eggs and feeding the eaglets after they hatch. Young eagles normally leave the nest 10 to 13 weeks after hatching. The first documented nesting by a pair of bald eagles at the Reserve took place during the winter of 1994-1995. They constructed a nest in a large white oak tree between the prairie and the estuary shore, not far from the railroad bridge. One egg was laid, but soon after the male deserted the nest. Remarkably, the female carried on alone, successfully incubating, hatching, and feeding the eaglet and eventually fledging a young eagle. This may be the only recorded incident of single-parent rearing by a bald eagle. The next winter the pair returned to the same nest (at least the same female, but perhaps with a different male partner). Two eggs were laid, but failed to hatch; later tests indicated the eggs were viable until day 27, about a week short of the necessary incubation time for a successful hatch. In 1997, two young eagles were fledged from the nest, but one was later found dead on the railroad tracks. The next winter the pair moved the nest to a location on the east side of the estuary, not far from the U.S. Route 6 bridge, again in a high white oak tree. Two young eagles were successfully fledged from this nest in 1998. The following year was the most successful to date, when 3 eagles were fledged in July 1999. Again in 2000, two eaglets were fledged.

*Figure 6.46. Belted kingfishers (*Ceryle alcyon*), male at top and female at bottom, painted on Lake Erie driftwood (artist: B. Hamler).*

*Figure 6.47. Bald eagle (*Haliaeetus leucocephalus*) soars over Old Woman Creek estuary (Gene Wright).*

Class Mammalia

As the name of this class implies, mammals nurse their young and in most cases bear them alive at an advanced stage of development—the young being nourished within the mother's uterus. As in birds, a high body temperature is maintained, permitting continuous activity in a wide range of climatic conditions, especially terrestrial environments (Young 1962). The presence of hair or fur in many members aids in temperature maintenance. The brain is highly developed, particularly in regard to learning ability.

A total of 52 species of mammals have been reported from the region surrounding Old Woman Creek (Appendix F). Of this number 27 species have been reported from studies within the Old Woman Creek watershed (Figure 6.48). Eleven of the mammalian species were extirpated from the region in the 1800s (Mayfield 1962). Of the various families of mammals, only the Family Vespertilionidae (bats) is poorly represented in the Old Woman Creek watershed (1 species out of 8 species reported in the region). Patrick (1981) and Bernhardt (1985) have recorded most of the initial sightings from the Old Woman Creek watershed.

Young red fox (*Vulpes vulpes*)

Raccoon (*Procyon lotor*)

Groundhog (*Marmota monax*) in live trap

White-footed mouse (*Peromyscus leucopus*)

White-tailed deer fawn (*Odocoileus virginianus*)

Bison (*Bison bison*) in domesticated herd

Figure 6.48. Representative mammals of Old Woman Creek estuary and watershed (Glen Bernhardt, Charles E. Herdendorf, Gene Wright).

American water lotus beds of Old Woman Creek estuary in 1888 (artist: Charles Courtney Curran).

Chapter 7. Ecology

Estuary Vegetation: Macrophytes

Adaptations for Aquatic Life

The dominant plants in the estuary are hydrophytes—plants adapted to life in the water or in water-saturated soil. The larger (macroscopic) water plants are collectively known as macrophytes and encompass the vascular plants (those with well-developed conducting tissue such as aquatic mosses, liverworts, ferns, and flowering plants) as well as macroalgae. The evolution of vascular plants from simple marine forms involved increasing adaptations to terrestrial environments. Thus, hydrophytic vascular plants show a reversal in this trend by their development of specific adaptations to cope with re-invasion of aquatic environments (Arber 1920). Within the estuary exists a spectrum of plants ranging from those which are normally terrestrial, but which are able to endure occasional submergence, to those which are wholly adapted to an aquatic environment, having lost their capacity for a terrestrial existence.

Aquatic macrophytes, especially submerged forms, have adapted to reduced solar radiation as a consequence of the light-attenuating and filtering effects of water. Because water loss does not present a problem as it does with land plants, a dense cuticle is not required to prevent desiccation except for exposed surfaces of emergent or floating leaves. Aquatic plants are unusually porous, their tissues containing large intercellular spaces that are commonly arranged to form chambers (aerenchyma tissue). This arrangement enhances gas exchange and provides leaf buoyancy. Most hydrophytes obtain oxygen and carbon dioxide by direct diffusion between leaf tissues and the water. The large air channels then provide internal gas exchange pathways for stem and root tissues which are typically buried in anoxic muds. This mode of gas exchange is necessary in aquatic plants because unlike terrestrial soil, water-saturated soils and estuarine sediments are generally devoid of gaseous oxygen.

In addition to dim light and scarce oxygen, aquatic macrophytes must cope with vertical and horizontal motion of the water, an absence of transpiration, and inadequate nutrient-absorbing capacity of roots (Pieters 1901). For submerged plants the problem of obtaining adequate oxygen is exacerbated by the low solubility of oxygen in water (generally <10 mg/l) and a much slower rate of oxygen diffusion in water. Because water-saturated soils of coastal wetlands are generally anaerobic, hydrophytes have developed anatomical and morphological adaptations to compensate for soil oxygen deficiency, such as: (1) transport systems which supply oxygen to underground organs from aerial structures, (2) metabolic mechanisms which function under anoxic conditions and in the presence of toxic metabolic products, and (3) detoxifying mechanisms. Aquatic plants also differ from upland species in that they must absorb nitrogen as ammonium cations (NH_4^+) because denitrifying micro-organisms (present in anaerobic soils) scavenge nitrate anion (NO_3^-), the usual source of this nutrient (Etherington 1983).

Some vascular aquatic plants have so completely adapted themselves to a watery environment that they have dispensed with roots except in germinating seedlings. With the exception of *Ceratophyllum* (coontail) and *Wolffia* (water-meal), all the vascular plants of the estuary produce some roots. In *Lemna* and *Spirodela* (duckweeds), roots are short and slender organs used to position and stabilize the plant in the water. Rooted aquatic plants such as *Myriophyllum* (water milfoil) and *Potamogeton* (pondweeds) primarily utilize their roots both as an anchoring system and for nutrient uptake (Wetzel 2001).

Owing to their hollow center and reduced vascular bundles, the stems of most monocot submerged and emergent plants are well adapted to water movements—numerous, often large, cavities supply an abundance of oxygen to all parts of the plant. A central canal is present in *Potamogeton* (pondweeds) and in some dicots, as *Ceratophyllum* (coontail), which functions as the xylem vessel in land plants. For added support, the stem is strengthened by thickening of the cellulose tissue (collenchyma) at the angles of the cell walls.

REPRODUCTION IN AQUATIC PLANTS

Pollen produced by terrestrial plants is transferred from one flower to another by agents such as wind and insects. Pollination takes place in the same way for aquatic plants having aerial flowers; for those that live beneath the surface, reproduction presents special problems. Thus, many aquatic plants rely mainly on vegetative reproduction. Others emerge to flower and subsequently drop their seeds into the water, revealing their terrestrial evolutionary ancestry by achieving fertilization only in an air medium. Few aquatic plants are capable of fertilization underwater because most pollen is not resistant to water; *Ceratophyllum demersum* (coontail) is one of the rare plants fertilized underwater. Stamens are released at maturity from submerged flowers and rise to the surface where pollen is discharged and hopefully sinks onto a pistillate flower (Voss 1985). More commonly however, reproduction in *Ceratophyllum* is by simple fragmentation of the rather brittle stem.

Certain submerged plants, such as *Potamogeton nodosus* (knotty pondweed), produce some floating leaves which serve as a platform for the support of flowering spikes. In other cases where there are no floating leaves and the plant remains totally submerged, special structures have evolved to bring the flower to the surface. *Elodea canadensis* (common water-weed) has developed a long, thread-like flower stem (up to 15 cm long), arising from the axil of a leaf, which bears a small pink female flower. Rare male flowers are produced underwater, the buds of which float to the surface to liberate pollen which blows along the water to pollinate the female flowers. This sexual method of reproduction in *Elodea* is uncommon—usually this plant reproduces vegetatively by a portion of its stem breaking away to form a new plant (Brown 1971).

Vegetative reproduction is common in most aquatic plants and many produce special overwintering structures known as turions. Turions are specialized short stems on which the leaves are closely packed. In *Elodea*, the parent plant persists all winter, but the leaves at the tips of the stems form compact tution buds that do not separate until spring. *Potamogeton cripus* (curly pondweed) produces turions in the form of side shoots which break away from the parent and grow fresh roots and leaves (Brown 1971). *P. pectinatus* (sago pondweed) overwinters by means of tubers produced at the ends of special roots (Pieters 1901).

Most aquatic plants produce fewer seeds than land plants and in some, seed production is seldom if ever seen. Active vegetative propagation and the perennial character of water plants have tended to reduce the importance of seed production. Pieters (1901) reported that studies of the seeds of aquatic and wetland plants show that most seeds are heavier than water and do not float unless they are adhering in masses or have a surface not easily wetted. Some float, but only for a few days. Seeds of aquatic plants are not well adapted to being spread by animal agents. Thus, most aquatic seed distribution is thought to be local.

ZONATION OF ESTUARY PLANT COMMUNITIES

As with many protected embayments, the cove-like margins of Old Woman Creek Estuary show a great regularity in the distribution of aquatic plants. Such zonation was first described for European lakes a century ago (Magnin 1893, Arber 1920). Passing into the estuary from the shore, the following order is generally observed. First, there is a littoral zone of plants standing out of the water—*Phragmites* followed by *Scirpus* or *Sagittaria* and *Sparganium*; next, a belt of submersed plants consisting of *Potamogeton* and *Ceratophyllum*; and still farther from shore, a zone of plants with floating leaves, among which *Nelumbo lutea* is the dominant species (Whyte 1996).

Arber (1920) points out that one of the chief factors determining this zonation is that plants with floating leaves can only flourish if guarded from the wind. For this reason they generally do not occur at great distances from the shore, except in very sheltered basins such as the estuary of Old Woman Creek or among protective stands of emergent reeds (Pieters 1894). Typically, where the water is more exposed to prevailing winds and moderate wave action, broad-leaved plants are absent, their place being taken by *Myriophyllum*, whose highly divided leaves are uninjured by wave motion (Matthews 1914). As a rule, submersed plants form a zone farther from the shore than floating-leaved plants because the latter shades the lower layers of the water, reducing sunlight penetration to a level insufficient to support a deeper flora (Arber 1920). Because much of the estuary is sheltered, beds of *Nelumbo* are scattered throughout the open water (Figure 7.1); as a consequence, the most favorable habitat for submersed plants is limited to the intervening spaces.

Figure 7.1. Nelumbo *beds in Old Woman Creek estuary*
*(*Lotus Lilies*, a painting by Charles Courtney Curran in 1888; courtesy of Terra Museum of American Art).*

Zonation within Old Woman Creek estuary—the arrangement of taxa in aquatic and marsh plant communities to form a series of bands more or less parallel to the shoreline—is largely influenced by water depth and soil moisture. The slope, or gradient, of the shore and nearshore bottom controls the width of the bands; steep gradients yield narrow bands whereas gentle slopes produce wider bands. Typically four distinct zone of macrophytes are present in Lake Erie coastal embayments and marshes such as Old Woman Creek Estuary: Zone 1–submerged plants; Zone 2–rooted, floating–leaved plants; Zone 3–emergent plants; and Zone 4–wet shore plants.

Zone 1–Submerged Macrophytes

Plants in this zone grow in water up to several meters deep and colonize the bottom as long as water clarity permits sufficient sunlight to penetrate for effective photosynthesis. The generally turbid condition in the estuary limits the photic zone to a depth to 0.5 to 0.8 m (Herdendorf and Wilson 1987). The dominant submerged plants in the estuary are *Ceratophyllum demersum* (coontail) and *Potamogeton pectinatus* (sago pondweed). *Ceratophyllum* lives suspended in the water column, while *Potamogeton* is rooted to bottom (Figure 7.2). Except for the flowers, all parts of these plants are adapted to live under water. Stems are weak and the general structure of the plants is loose since water buoyancy reduces the requirement of the rigid support needed for plants living in an air environment. Stoma, the pores on the underside of leaves used for gas exchange in air, are also reduced or vestigial.

In response to reduced light illumination underwater, photosynthetic pigments (e.g. chlorophyll and carotenoids) are concentrated in surface (epidermal) tissue (Wetzel 1983). Submerged plants commonly have numerous and finely divided leaves and green (photosynthetic) stems to optimize the reduced light reaching them. These slender and threadlike leaves maximize surface area–to–volume ratios (thereby facilitating gas exchange) and minimize resistance to water currents. For example, *Ceratophyllum* leaves are split into many divisions, while *Potamogeton pectinatus* leaves are narrow and elongated. *Potomogeton pectinatus* also demonstrates a special adaptation for growth in turbid waters, such as that found in Old Woman Creek estuary. Mostly submerged, this aquatic plant has a crown of leaves on the upper portion of the stem that fan out near the water surface (Figure 7.3) to maximize exposure to available sunlight (Langlois 1954).

*Figure 7.2. Sago pondweed (*Potomogeton pectinatus*), a submerged plant rooted to the bottom (Charles E. Herdendorf).*

Also in this zone, *Elodea canadensis* (common waterweed) was first observed in the estuary in 1995 (Whyte 1996). Although this species was found in Old Woman Creek above the estuary in 1979, it has very limited distribution in both habitats. Thin leaves (e.g. two-cell thickness of *Elodea* leaves) make the most of dim light, but they also require adaptations to offset the turbulent motion of water. For example, ribs in broad leaves provide needed rigidity (Pieters 1901).

Another plant of this zone, the exotic *Myrophyllum spicatum* (Eurasian water milfoil), was first observed in the estuary in 1992 (Whyte 1996) but as of 2001 it has not firmly established a population in the estuary. Fragments of this invasive plant have been observed floating in the lower reaches of the estuary in each of the years after 1992, but apparently have been unable to root and form a viable reproducing population. Since all fragments have been observed near the estuary mouth, it appears that Lake Erie is the source of this exotic species.

Zone 2–Floating-Leaved Macrophytes

Floating-leaved plants are of two principal types, those attached to the bottom and those freely floating. Attached types are primarily flowering plants (angiosperms) that occur in water 0.5 to a few meters deep. Freely floating types are not rooted to the bottom and tend to accumulate in shallow, protected areas. Because of the generally turbid water and shallow depths of the estuary, zones 1 and 2 are often superimposed to form a single zone encompassing most of the open waters of the estuary. The dominant aquatic macrophytes in this zone are *Nelumbo lutea* (American water lotus), *Nymphaea odorata* (white water–lily, Figure 7.4), and to a lesser extent *Nuphar lutea advena*

Figure 7.3. Potomogeton pectinatus *(sago pondweed) showing crown of leaves on the upper portion of the stem that fan out near the water surface (Fassett 1957).*

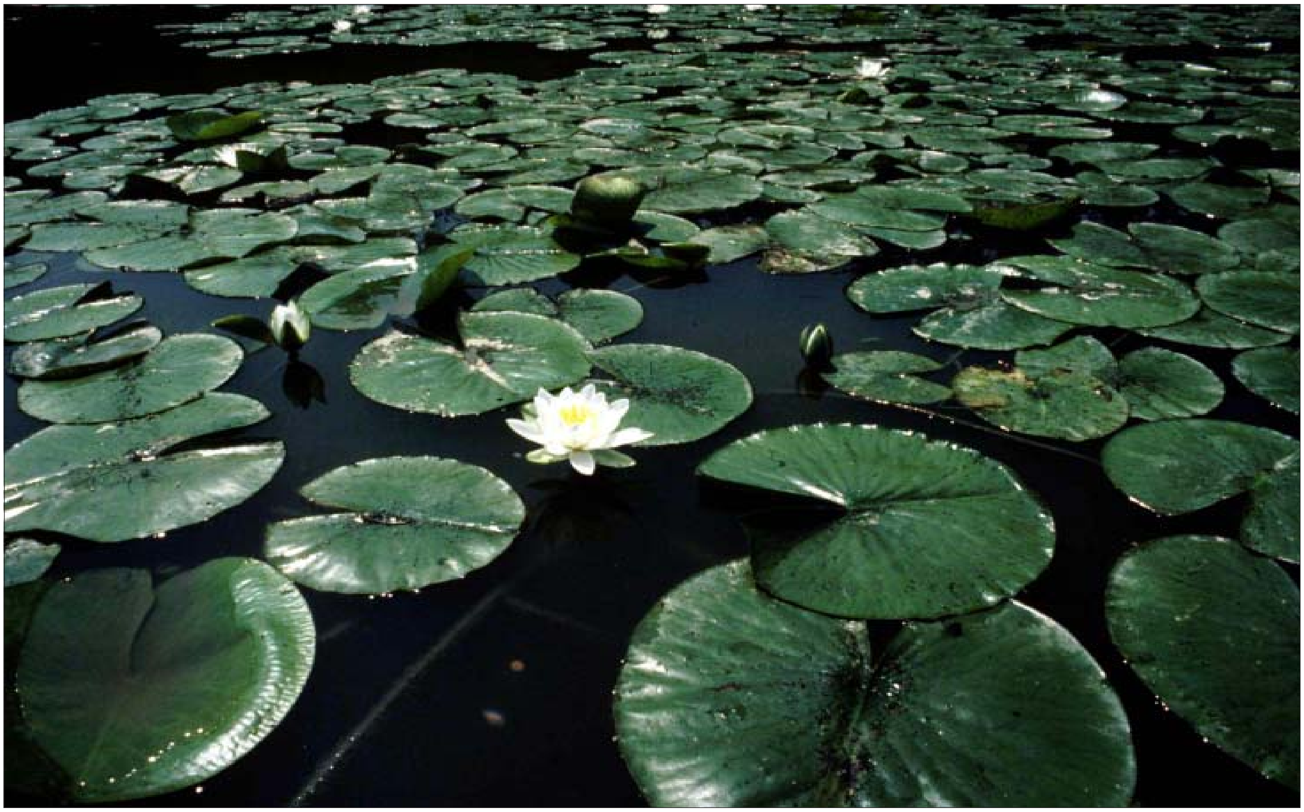


Figure 7.4. White water-lily (Nymphaea odorata*), a rooted, floating-leaved plant of the estuary (Gene Wright).*

(spatterdock). Floating *Lemna minor* (duckweed) often forms thick mats in the quiet waters among the lotus beds in early autumn (Figure 7.5).

The structure of floating leaves is strikingly different from that of submerged leaves in response to their dissimilar environments. The cells of the upper epidermis of the floating leaves are smaller, the cell walls are thicker, and more irregular in outline. Stomata are confined to the upper surface of the floating leaf, while they are virtually absent on the submerged leaf. Floating leaves are of finer texture than submerged ones and have a waxy covering to protect them from water injury. In *Nelumbo lutea* this protection is provided by numerous papillae (hairs), each arising from an epidermal cell. These fine projections hold a layer of air so that water falling on the leaf stands in large drops, as if on an oiled surface, until it can run off (Pieters 1901). *Nelumbo* is unique among the floating-leaved plants in the estuary in that it produces two distinct cohorts of leaves: the first are floating and emerge in late May while the second are aerial leaves that appear in late June or early July (Whyte 1996). The aerial leaves are generally above the range of seasonal water level fluctuations (Figure 7.1).

*Figure 7.5. Duckweed (*Lemna minor*) forms floating mats in protected coves of the estuary (Linda Feix).*

The boundary layer between air and water is a challenging environment for aquatic plants, where temperatures, water levels, current, and clarity vary from day to day as well as seasonally. The floating leaves of *Nuphar lutea advena* and *Nymphaea odorata* are well adapted to these conditions with long, bending stems (flexible petioles) that can alter their position in the water to keep the leaves on the surface. The leaves also have a waxy upper surface that resists wetting and desiccation. Gas exchange pores (stomata) are distributed on the upper surface instead of the lower as they are in terrestrial plants.

Zone 3–Emergent Macrophytes

Plants in this zone grow on water-saturated or shallowly submerged soils, i.e. water table 0.5 m below the soil surface to sediment covered by up to 1.5 m of water (Wetzel 1983). Most are perennial with rhizomes or corms embedded in the soil. In many species, morphologically different submerged or floating leaves precede mature aerial leaves. All produce aerial reproductive organs. Common plants of Old Woman Creek estuary in this zone include: *Leersia orzyoides* (rice cut-grass), *Phalaris arundinacea* (reed canary–grass), *Phragmites australis* (common reed), *Scirpus fluviatilis* (river bulrush), *Hibiscus moscheutos* (swamp rose-mallow, Figure 6.15), *Polygonum amphibium* (water smartweed. Figure 6.14), *Typha angustifolia* (narrow-leaved cattail, Figure 7.6), and various species of *Carex* (sedges).

Emergent monocotyledons, such as *Phragmites* and *Scirpus*, produce erect, linear leaves from an extensive anchoring system of rhizomes. Epidermal cells are elongated parallel to the long axis of the leaf, which allows flexibility for bending (Wetzel 1983). However, the cell walls are heavily thickened with cellulose, which provides the necessary rigidity. The internal tissue (mesophyll) is generally undifferentiated and contains large air spaces (lacunae). Emergent dicotyledons, such as *Hibiscus moscheutos* and *Polygonum amphibium* (water smartweed), produce erect, leafy stems which show greater anatomical differentiation. The internal tissue of the leaves is divided into typical upper palisade (elongated cells) layer and lower spongy (loosely packed cells) layer.

The roots and rhizomes of emergent macrophytes are permanently embedded in anaerobic sediment and are dependent on the aerial shoots for a supply of oxygen. Young, submerged foliage must be capable of respiring anaerobically until aerial growth is attained, since oxygen concentrations in water are very low in comparison to that in air. Once the foliage has emerged, the intercellular spaces increase in size, thus facilitating gaseous exchange between photosynthetic cells and the atmosphere. Rhizomes are capable of withstanding prolonged periods (up to a month) of low oxygen supply (Wetzel 1983).

*Figure 7.6. Narrow-leaved cattail (*Typha angustifolia*), an emergent plant that grows at the fringes of the estuary (Gene Wright).*

The emergent monocot *Sparganium* (bur-reed) demonstrates a variety of adaptations to match the different conditions experienced by various parts of the plant. Examination of successive cross-sections of the bur-reed shoot shows that the emergent leaf has a tough rigid structure with dense tissue that withstands the stress at the air-water interface. Farther down the shoot the tissue gets more spongy and full of air, an adaptation for supplying oxygen to the roots (Angel and Wolseley 1982).

Production of adventitious "water roots" close to a seasonally flooded surface is a common strategy for many water-tolerant species of the swamp forest. For example, *Salix alba* (white willow) forms a large tussock of such roots above the normal flood level. In woody plants such as *Salix* (willows) and *Nyssa sylvatica* (black gum), flooding first causes an overgrowth of lenticel tissue (hypertrophy) to form a callus from which adventitious roots then emerge close to the better oxygenated air-water interface. Some herbaceous plants behave similarly, for example the flood-tolerant *Epilobium glandulosum* (willow-herb) has hair-like roots for several cm above the stem base that produce adventitious surface roots on flooding.

Emergent plants of the estuary marshes, such as *Phragmites australis* (common reed), *Typha angustifolia* (narrow-leaved cattail), and *Scirpus fluviatilis* (river bulrush), grow in the most severe of all waterlogged environments, their roots and rhizomes in anaerobic mud and their leaves in a very exposed, often sunlit environment. Growth habits of monocotyledons make such plants well suited to this situation, particularly their free adventitous rooting and the frequent absence of stem tissue between the leaf and roots which facilitates the transport of oxygen (Etherington 1983).

Wetland plants of the estuary such as *Juncus effusus* (common rush), *Sagittaria latifolia* (arrowhead), *Scirpus validus* (soft-stem bulrush), *Sparganium eurycarpum* (bur-reed), *Typha latifolia* (broad-leaved cattail) are all well supplied with running rootstocks. Those of an association of *Scirpus* or *Typha* are particularly strong and wide spreading with each plant connected to all others of its species by thick rhizomes.

Zone 4–Wet Meadow and Floodplain Macrophytes

Lying adjacent to the shoreline of the estuary, this is a transition zone between estuarine and upland habitats (Figure 7.7). Plants in this zone grow in soil that is usually saturated with water to within a few centimeters of the surface. During wet periods the nearly flat to gently sloping terrain can be shallowly flooded and during droughts the water table can drop tens of centimeters below the surface. The plant community in this zone is represented by many monocots, including sedge genera such as *Carex*, *Cyperus*, *Eleocharis*, and *Scirpus*, rushes of the genus *Juncus*, and grasses of the genera *Calamagrostis*, *Cinna, Echinochloa*, *Glyceria*, *Leersia*, *Phalaris*, and *Phragmites* (Figure 2.12). Herbaceous dicots are represented by a wide variety of genera, including *Ranunculus* (buttercups and crowsfoots), *Polygonum* (smartweeds), *Rumex* (docks), *Lycopus* (water horehounds), *Asclepias* (milkweeds), *Verbena* (vervains), *Mentha* (mints), *Scutellaria* (skullcaps), *Mimulus* (monkey-flowers), *Galium* (bedstraws), and composite genera such as *Aster*, *Bidens* (beggarticks), *Eupatorium* (bonesets), and *Solidago* (goldenrods).

The wet floodplain adjacent to the south basin of the estuary also supports many woody plants and can aptly be termed a swamp forest. Typical woody genera include *Acer* (maples), *Carya* (walnuts), *Cephalanthus* (buttonbushes), *Cornus* (dogwoods), *Corylus* (hazelnuts), *Populus* (cottonwoods), *Quercus* (oaks), *Salix* (willows), *Tilia* (basswoods), and *Ulmus* (elms). Tree species such as these create a canopy that changes the character of wetlands from sunlit marshes with soft-stemmed plants to shady, woody swamps with relatively minor amounts of herbaceous biomass in the understory.

Like the emergent zone, wet meadows are highly productive in terms of biomass and fulfill effective water filtering functions. The juncture of the stems and roots for plants in this zone is typically just above the water table during the growing season. Thus, many of the species found in this zone must grow in a wetland and are termed obligate hydrophytes. However,

Figure 7.7. Wet meadow grasses fringe the mudflats of the estuary (Charles E. Herdendorf).

because of this zone's transition position between the estuary and the uplands, other species found in the zone have the ability to live in semi-dry situations and are termed facultative hydrophytes.

TRENDS IN MACROPHYTE POPULATIONS

Great Lakes coastal wetlands are among the most dynamic wetland types. This dynamic nature is largely the result of the variable water levels in the five Great Lakes. The impact of seasonal and annual variations in water levels on the wetland vegetation can be significant. During high lake levels, as much as 50% of the emergent plant zones can become open water (Jaworski et al. 1979). Kelley et al. (1985) reported similar results from Pentwater Marsh, Michigan. Researchers have also reported this change in aquatic flora in Old Woman Creek (Klarer and Millie 1992, Whyte 1996, Whyte et al. 1997, Trexel-Kroll 2002).

The first detailed survey of the aquatic flora of Old Woman Creek estuary was conducted by John Marshall in 1974 (Marshall 1977, Marshall and Stuckey 1974). At that time, lake levels had risen to very high levels after a 15+year period of moderate to low levels (Figure 7.8). Lake levels remained elevated from 1974 through the spring of 1999, with record high levels recorded in 1985 and again in 1986. Marshall (1977) reported five distinct beds of emergent or floating-leaved species in the estuary in 1974. Dominant species included: *Peltandra virginica*, *Nelumbo lutea*, and *Polygonum amphibium*. Klarer and Millie (1992) examined the changes in macrophyte flora from 1974 through 1989. They prepared a map of the different regions of the estuary and a table recording the changes in flora from Marshall's original survey through 1989.

For this site profile, we have employed the same region map developed for the 1992 study (Figure 7.9) and a table from that study has been modified (Table 7.1) to incorporate the more recent floral studies of Whyte (1996), Whyte et al. (1997), Trexel-Kroll (2002) and Klarer (unpublished data). From 1977 through 1999 *Nelumbo lutea* dominated the macrophyte flora in Old Woman Creek estuary. In 1999 water levels declined to levels similar to those of the 1960s (Figure 7.8). With these declining water levels, the aquatic macrophyte community underwent a major shift in species composition. The dominant *Nelumbo*, the

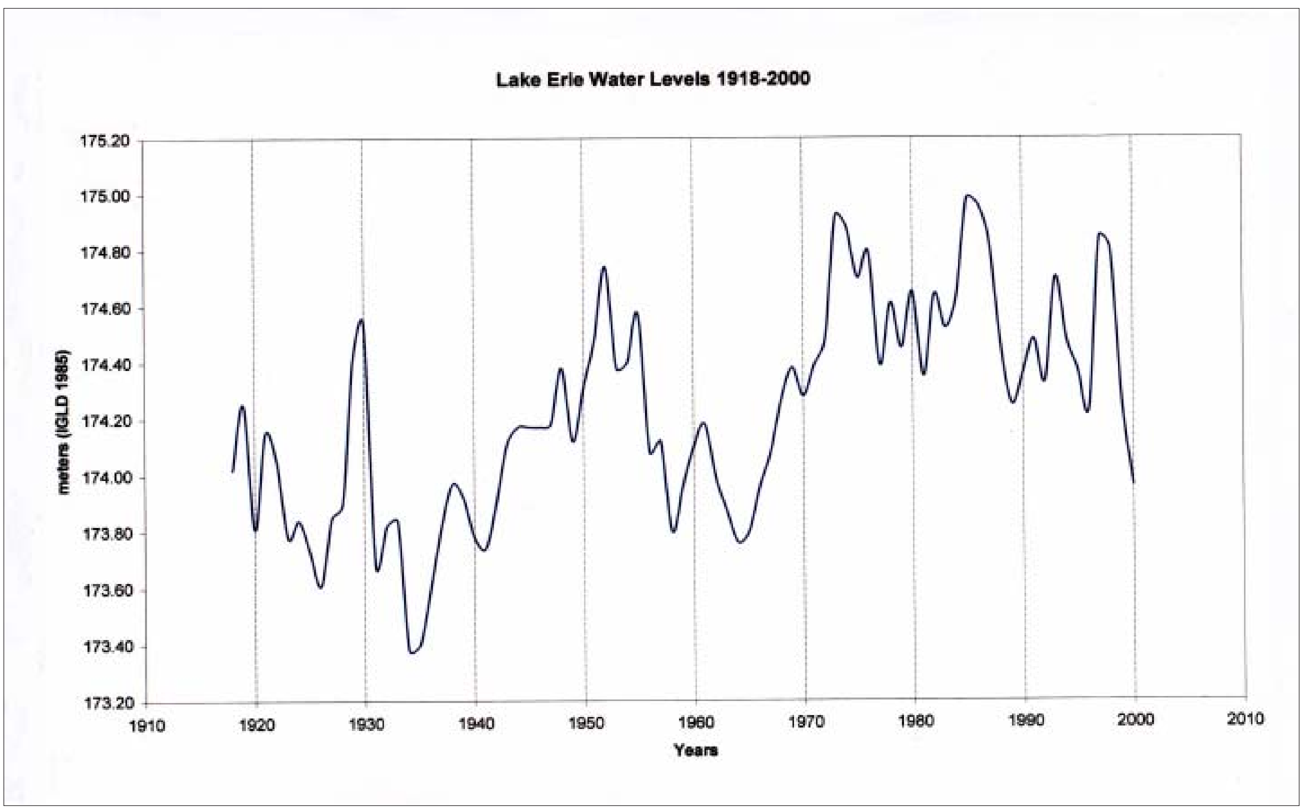


Figure 7.8. Mean annual Lake Erie water levels from 1918 to 2000 (NOAA).

TABLE 7.1. MACROPHYTE DOMINANCE BY AREAS OF THE OLD WOMAN CREEK ESTUARY FROM 1973 TO 2001

Site	1973	1984	1985	1986	1988	1989	1993	1994	1999	2000	2001
1	Peltandra virginica Potamogeton pectinatus Potamogeton nodosus Nymphaea odorata[1]	N. lutea P. pectinatus	N. lutea P. pectinatus	*	*	N. lutea P. pectinatus	N. lutea N. odorata Ceratophyllum demersum P. pectinatus	N. lutea N. odorata C. demersum P. pectinatus	N. lutea N. odorata C. demersum P. pectinatus	N. odorata Leersia oryzoides N. lutea Sagittaria latifolia	L. oryzoides Lemna minor S. latifolia N. odorata
2	Nelumbo lutea N. tuberosa P. pectinatus P. Nodosus	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea *Emergents	N. lutea *Emergents
3	Polygonum coccineum Hibiscus palustris Cornus drummondi	*	*	*	*	*	N. lutea	N. lutea	N. lutea	*Emergents N. lutea	*Emergents N. lutea
4	N. lutea Nuphar advena	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea *Emergents
5	P. coccineum N. advena	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea *Emergents	*Emergents	*Emergents
6	N. odorata	N. odorata	N. odorata	N. odorata	N. odorata	N. odorata	*	*	*Emergents	*Emergents	*Emergents
7	Peltandra virginica P. pectinatus	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea	N. lutea C. dermersum	N. lutea C. dermersum	N. lutea	*Emergents N. lutea	*Emergents N. lutea
8	*	N. lutea	N. lutea	*	*	*	N. lutea	N. lutea	N. lutea	*Emergents	*Emergents

NOTES:

Site locations are shown on Figure 7.9. If multiple species are listed for a particular site, they are given in descending order of abundance.

"*" denotes no vegetation reported.

"* Emergents" denotes undifferentiated emergent species including varying proportions of the following taxa: *Leersia oryzoides*, *Echinochloa* spp., *Phalaris arundinacea*, *Carex* spp., *Scirpus validus*, *Typha* spp., *Sparganium eurycarpum*, and *Sagitaria latafolia*.

1 *Nymphaea odorata* is the new name of *Nymphaea tuberosa* as recorded by Marshall (1976), Klarer and Millie (1992), and Whyte (1996)

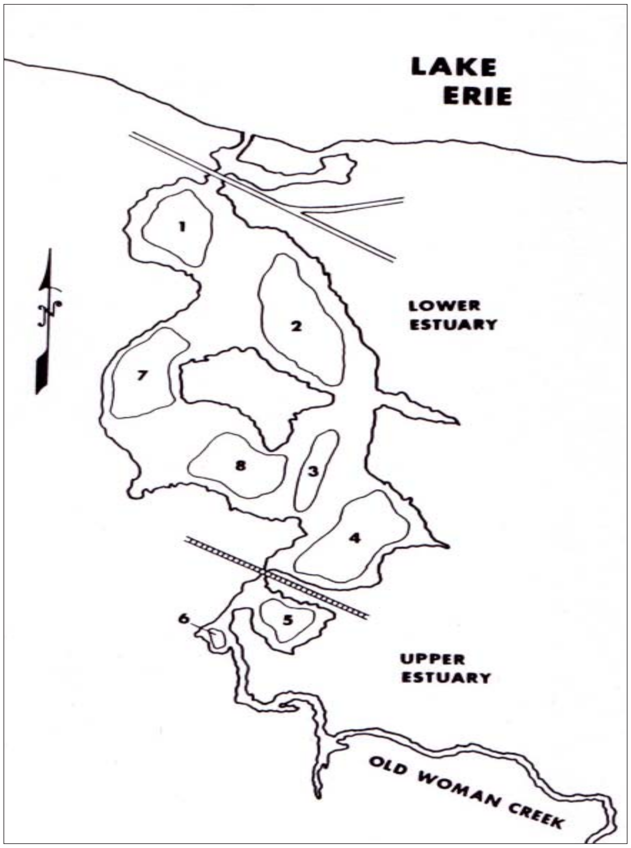


Figure 7.9. Old Woman Creek estuary map showing site locations of aquatic macrophyte beds and numbering system (Klarer and Millie 1992).

major species in the estuary from the late 1970s through 1999 (Figures 7.10 to 7.12), was replaced by emergent species in both 2000 and 2001 (Trexel-Kroll, 2002). Total vegetation cover rose from 40% in 1999 to greater than 70% in 2000 and 2001. The percent cover of emergent plants in the estuary rose from less than 10% in 1999 to greater than 45% in 2000 and even slightly greater in 2001. Although the areal extent of the vegetation did not markedly change between 2000 and 2001, there were noticeable changes in the species composition. The relative importance of floating-leaved species declined while duckweeds, submergents, and particularly emergent species increased. In the northwest embayment during 2001, the emergents were nearly equally divided between grasses—*Leersia*, *Echinochloa*, *Phragmites* (35% of total vegetation) and non-grasses—*Polygonum*, *Typha*, *Sparganium*, *Sagittaria* (42% of total vegetation), while in the major beds south and west of the island, the grasses—particularly *Leersia* and *Echinochloa*—accounted for 55% of the vegetation and the non-grasses only 22%.

During the period of *Nelumbo* dominance, this species demonstrated two distinct growth patterns: a general expansion in coverage in the estuary and a cyclic pattern of expansion and contraction within individual beds (Whyte et al. 1997). Over this 20+ year period, the percentage of *Nelumbo* cover ranged from 5.2% (1977) up to 35.6% (1993) coverage (Table 7.2). This cyclic expansion and contraction in an individual bed is readily apparent when examining the yearly *Nelumbo* distribution maps in Whyte et al (1997) (Figure 7.10). The major *Nelumbo* bed due north of the island expanded from 1977 to 1984, when it broke into two separate beds. The northern portion of the bed continued to migrate northwest in the estuary toward the mouth, from 1984 through 1989, while the southern part of the bed gradually disappeared.

TABLE 7.2. PERCENTAGE COVER OF *NELUMBO LUTEA* IN ESTUARY

Year	Percent Coverage
1977	5.2
1978	5.4
1979	12.8
1984	21.5
1985	16.6
1986	17.8
1988	20.3
1989	10.9
1993	35.6
1994	34.3
1995	34 (estimated)
1998	29.0
1999	30.4
2000	22 (estimated)
2001	20 (estimated)

Data Sources: Whyte 1999 and Klarer, unpublished

In summary, the aquatic macrophyte communities in Old Woman Creek estuary are very dynamic. The size and locations of the different beds change each year. During high water years (1980-1999) the vascular flora was dominated by *Nelumbo lutea*, while the emergent vegetation was largely confined to the shoreline edges of the estuary. When Lake Erie water levels dropped in 1999, many of the mudflat areas that had been underwater from 1980 through 1999 were exposed during the spring of 2000. These areas were quickly colonized by emergent vegetation.

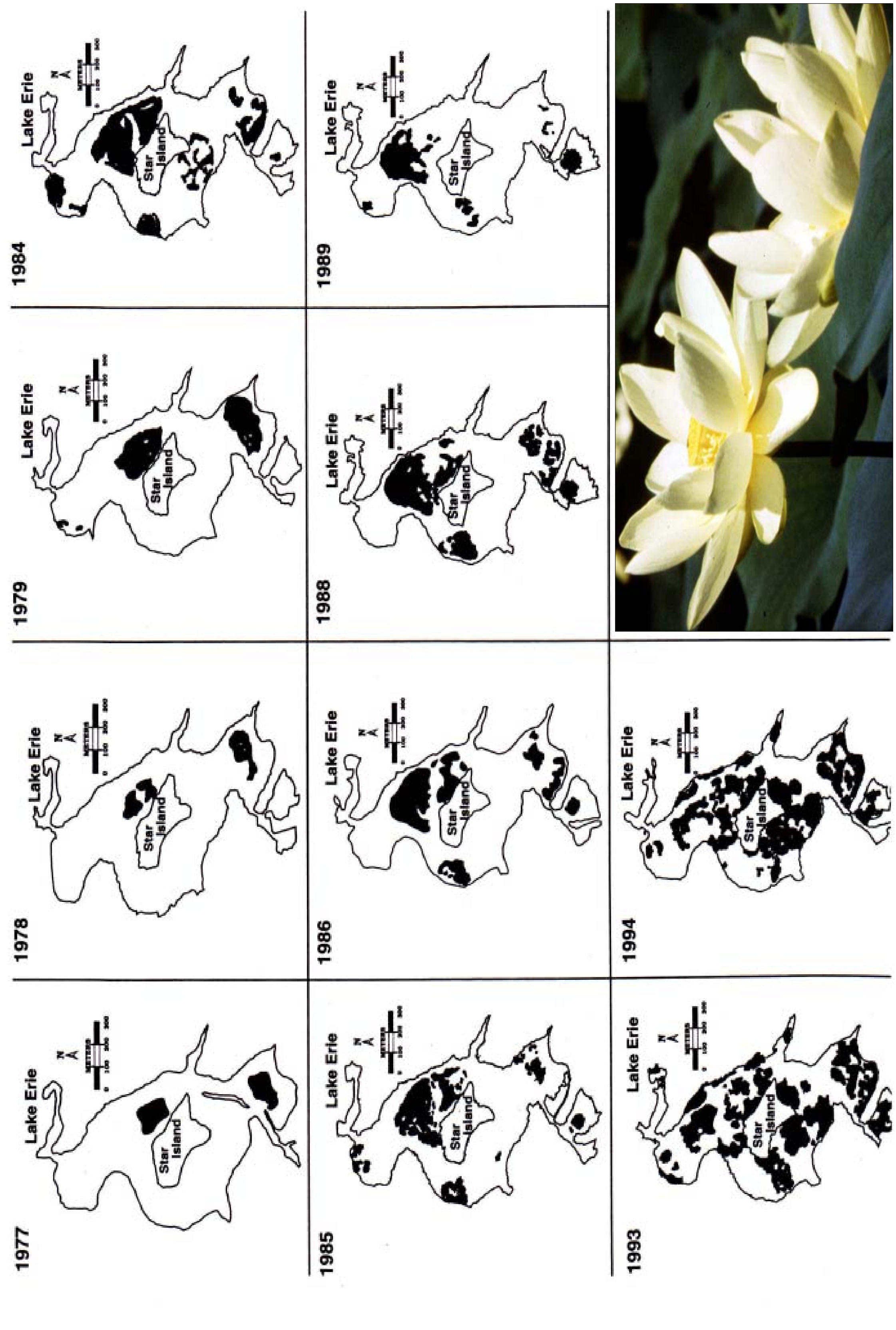


Figure 7.10. Distribution of Nelumbo lutea *in Old Woman Creek estuary from 1977 to 1994 (Whyte et al. 1997).*

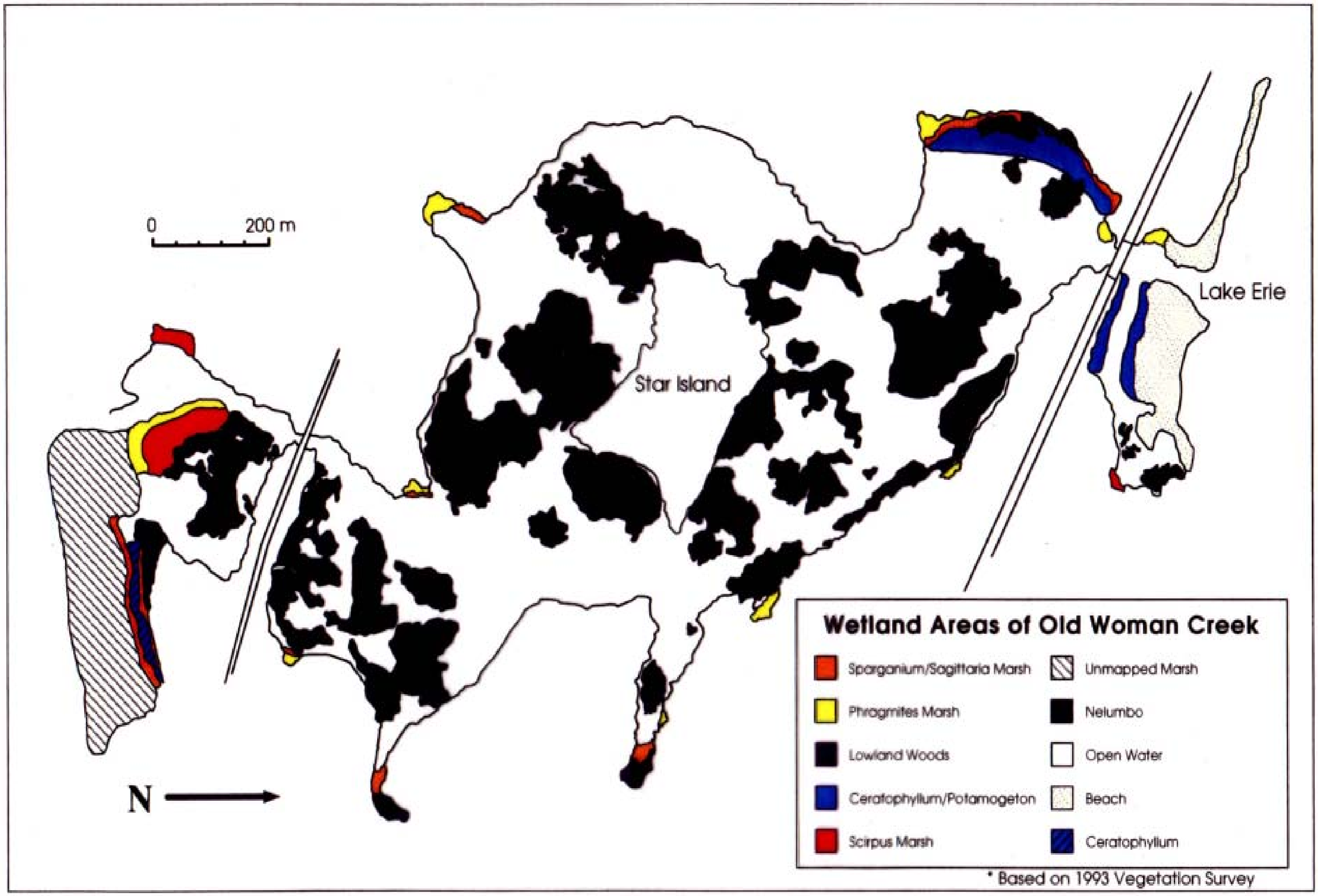


Figure 7.11. Detail of wetland vegetation distribution in Old Woman Creek estuary for 1993 (Whyte 1996).

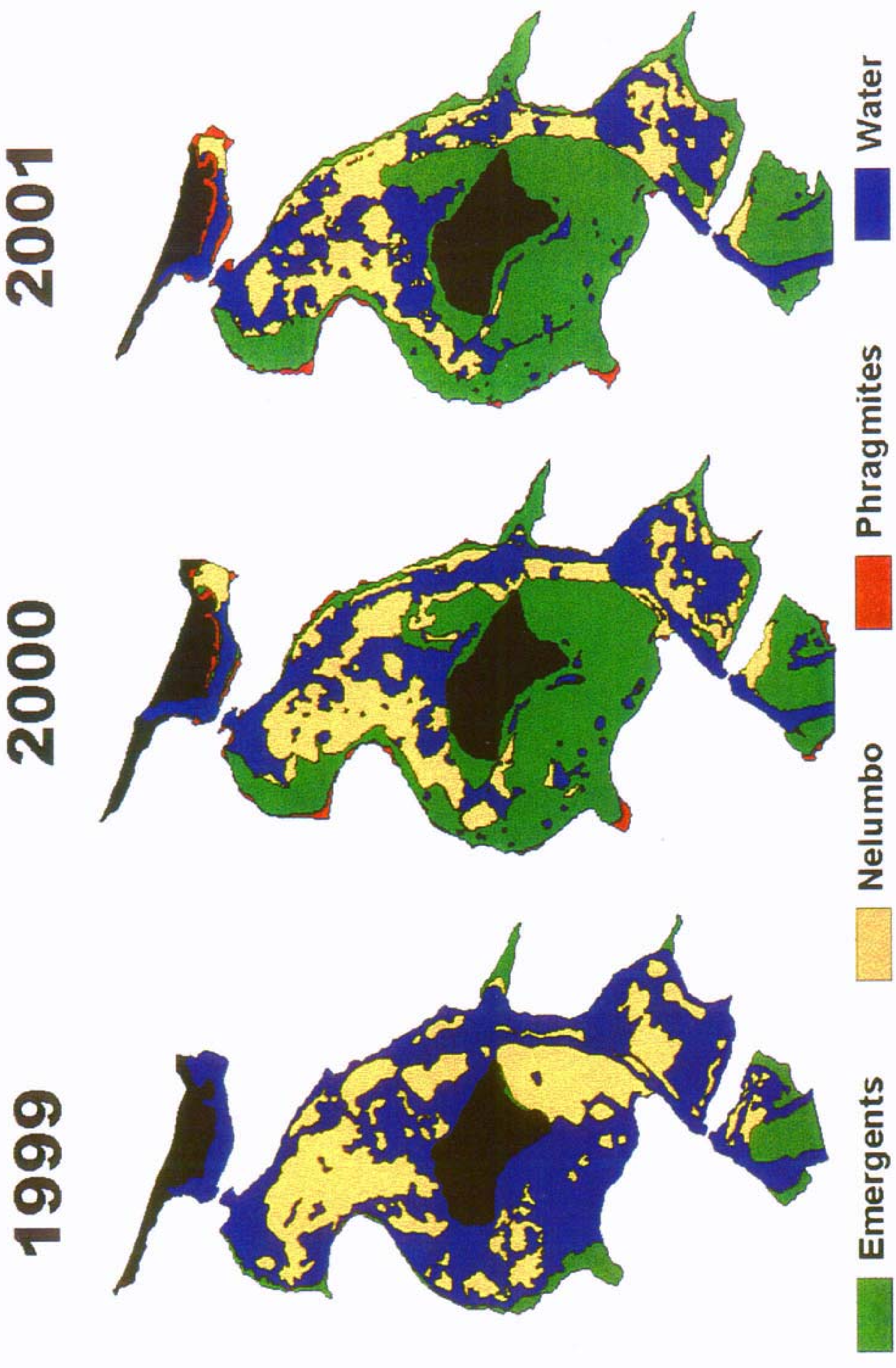


Figure 7.12. Distribution of macrophyte vegetation in Old Woman Creek estuary for 1999, 2000, and 2001 (Trexel-Kroll 2002).

INVASIVE SPECIES

Within Old Woman Creek estuary, three aquatic macrophyte species are deemed invasive species and have either been eradicated or monitored. *Lythrum salicaria* (purple loosestrife) and *Myriophyllum spicatum* (Eurasian water–milfoil) are both non-native, while *Phragmites australis* (common reed) has been considered a native species, but perhaps is an alien variety (Weinstein et al. 2002).

Lythrum salicaria, a major invasive of Lake Erie coastal wetlands, was first reported in Old Woman Creek by Marshall (1977). Although Marshall classified this species as common, it has yet to become a dominant species in the estuary. A control program has been in place at Old Woman Creek since the mid-1980's. When individual plants are discovered, they are eradicated—either by physically removing the plant or applying herbicides directly onto the plant. Despite this program, Whyte (1996) and Trexel-Kroll (2002) both reported this species in their vegetation studies in the estuary. It appears that this species can be controlled, but not eradicated in the estuary. Only when a lake-wide control program is initiated is there any chance of eradicating this invasive species from the estuary.

Myriophyllum spicatum was first reported in the estuary in 1992 in the northwest embayment (the small bay directly south and southwest of the U.S. Route 6 Bridge), although Marshall (1977) reported the presence of the native *Myriophyllum exalbescens* in the estuary. Whyte and Francko (2001) reported on the growth of *M. spicatum* from its first reported sighting in 1992 through 1997. Although this species was found in 1998 and 1999 by Klarer (unpublished), Trexel-Kroll (2002) did not report this species in her detailed study of the flora in this embayment during 2000 and 2001. Whyte and Francko (2001) pointed out that the available evidence supports the idea that Lake Erie is the source of this species for Old Woman Creek. All sightings have been near the mouth. The shallow nature of the wetland, exacerbated by the natural autumn and winter drawdown, frequently creates exposed mudflats. This, coupled with the winter periods where freezing temperatures and ice formation is common, creates an environment that is detrimental to the successful establishment of *M. spicatum*. They believed that the barrier beach may also play a major role in the dynamics of this invasive species in the estuary. In 1994, when no specimens were found in the estuary, the mouth was open through the barrier beach to Lake Erie only 44% of the year; whereas, in 1993 and 1995 it was open 58% and 77%, respectively.

Phragmites australis has probably been observed along the Lake Erie shores since before the arrival of the European explorers. Stuckey (1989) considered this species a native which had not significantly altered its distribution for the past 90+ years. This species was not found by Marshall (1977) in the estuary in the mid-1970s. It was believed to have entered the estuary in the mid-1980s and was first observed near the barrier beach (Klarer, personal observation). Whyte (1996) reported that small dense stands of *Phragmites* were confined to several low relief shoreline floodplain areas from 1993 through 1995. Trexel-Kroll reported that in 2000 and in 2001 with lowered water levels, *Phragmites* expanded into the newly created emergent zones in the wetland. By the end of the 2001 growing season this species was present in scattered beds throughout the estuary. She considered that this expansion was due in part to direct expansion of existing stands via rhizomes. In five separately monitored *Phragmites* beds in the estuary there was more than a four-fold increase in the size of the beds from 2000 to 2002 (40.7 m^2 in 2000 versus 182.5 m^2 in 2001). In new non-adjacent beds, translocation of rhizome fragments was probably the means of expansion. A *Phragmites* control program employing cutting and/or direct herbicide application to the stems has been underway since the late 1990s.

RELATIONSHIP OF AQUATIC PLANTS TO AQUATIC ANIMALS

Most of the leafy aquatic plants in Old Woman Creek estuary serve as shade or protection for fish, while some support algae or small animals which serve as food for fish. Krecker (1939) studied the invertebrate animal populations associated with aquatic plants in western Lake Erie. He noted that submerged, leafy types of vegetation are more densely populated than emergent, hard-surfaced, non-leafy forms. *Myriophyllum spicatum* (water milfoil) and *Potamogeton crispus* (curly pondweed) supported by far the densest populations (440 and 337 individuals per linear meter), followed by *Elodea canadensis* (common water-weed) and *Potamogeton pectinatus* (sago pondweed) with lesser, but substantial numbers (173 and 143/m). *Vallisneria americana* (wild celery)—a species not yet reported in the estuary, but present in western Lake Erie harbored only negligible numbers of aquatic invertebrates (9/m). Midge larva (Chironomidae) and freshwater annelids (Oligochaeta) comprised 45 and 44%, respectively, of the invertebrates living on *Potamogeton pectinatus*, one of the most common submersed plants in the estuary. The finely divided, narrow leaves of *Myriophyllum spicatum* and *P. pectinatus*, are well suited to these animals; midges cling to such leaves with their hook-bearing appendages and annelids coil about them. Conversely, *Vallisneria* offers a broad, smooth surface. The broader leaves of *Elodea* and *P. crispus* harbor a higher percentage of sessile forms (rotifers, bivalves, hydrozoans, and bryozoans) than narrow-leaved plants.

Estuary Vegetation: Phytoplankton and Phytobenthos

Plankton consists of the floating organisms in the estuary and Lake Erie—both plant (phytoplankton) and animal (zooplankton)—whose movements are more or less dependent on currents. While some phytoplankters have the ability to rise in the water column and certain zooplankters exhibit active swimming movements that aid in maintaining vertical position, as a whole, plankton tends to settle and most plankters are unable to move against a current. The phytoplankton of Old Woman Creek, the estuary, and the nearshore waters of Lake Erie consists of a diverse taxonomic assemblage of primarily microscopic algae. A fundamental characteristic of algae is the presence of photosynthetic pigments, such as chlorophyll (*a, b, c, & d*), carotenes, xanthophylls, and chromoproteins (phycocyanin and phycoerythrin). Chlorophyll *a* is the primary pigment in all oxygen-evolving photosynthetic organisms, and is present in all algae (Wetzel 2001). As discussed in Chapter 6, algal taxonomy at the division level is based on the specific combinations of other pigments with Chlorophyll *a*. This results in a characteristic color from which the common name of the algal divisions are derived: blue-green algae (Cyanobacteria), green algae (Chlorophyta), yellow-green and golden-brown algae and diatoms (Chrysophyta), euglenoids (Euglenophyta), yellow-brown algae and dinoflagellates (Pyrrhophyta), and red algae (Rhodophyta). Many of these groups also produce benthic forms associated with sediment, sessile on macrophytes, or attached to hard substrates for a portion of their life cycle.

The algae of Lake Erie have long been studied, with major studies dating back to the beginning of the 20th century and before (Vorce 1880, Pieters 1901, Snow 1903). Many of these early workers included adjacent coastal wetland areas in their studies of the lake algae. Although the first study concentrating on the phytoplankton in the tributaries and coastal areas of Lake Erie was conducted in the 1920's (Wright et al. 1955), very few studies have concentrated on the coastal wetlands of Lake Erie. Sullivan (1953) examined the plankton in the ten major estuaries along the Ohio shore of Lake Erie. From this work he concluded that the majority of the phytoplankton in the estuaries was of lake origin, being introduced into the estuaries by influxes of lake water. Kline (1981) in a study of the nearshore zone phytoplankton of the Lake Erie central basin also reported a strong similarity between lake and tributary phytoplankton populations. However, he did point out that the further the sampling site was from the lake, the greater the divergence from lake populations. Frederick (1975) examined changes in phytoplankton in the East Harbor up through 1974. Only 31% (47 of 151 taxa) of the previously reported algal species were still found at East Harbor by 1974, and there were 52 new records for Lake Erie. The changes he ascribed to human activities, particularly dredging activities in 1967.

Taft and Taft (1971) authored a taxonomic survey of the algae of the western basin of Lake Erie, which included various wetland areas on Bass Islands and Catawba Peninsula. The diversity of the algal flora in these wetland areas is readily demonstrated by the total number of species reported from each area (Table 7.3). The relative high number of Chlorophyceae in the marshes of South Bass Island and Middle Bass Island is due to the diversity of desmids found in these marshes, a group that is poorly represented in Old Woman Creek. The high number of the Euglenophyta found in Old Woman Creek may be a result of the transitory nature of phytoplankton populations in this estuary. A complete list of the algae reported from Old Woman Creek, its estuary, and the nearshore waters of Lake Erie is presented in Klarer et al. (2001).

The algae in a wetland area such as Old Woman Creek estuary occupy a series of overlapping habitats. Bolsenga and Herdendorf (1993) defined six algal communities in Lake Erie: phytoplankton, epipelon, epiphyton, epilithon, epipsammon, and metaphyton (Figure 7.13). The phytoplankton includes all algae

TABLE 7.3. RELATIVE ABUNDANCE OF ALGAL SPECIES FOR SEVEN WESTERN LAKE ERIE MARSH AREAS

Taxonomic Group	South Bass Island	Middle Bass Island	North Bass Island	Kelleys Island	Pelee Island	Catawba Penisnula	Old Woman Creek
Cyanophyta	56	36	20	15	6	22	44
Rhodophyta	1	0	1	1	0	0	0
Chrysophyta-Chrysophyceae	19	15	10	4	0	2	31
Chrysophyta-Xanthophyceae	6	7	7	3	7	1	6
Chrysophyta-Bacillariophyceae	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	(311)
Pyrrhophyta-Dinophyceae	3	5	2	0	1	1	10
Cryptophyceae	1	0	0	0	0	0	21
Euglenophyta	11	6	4	4	1	0	77
Chlorophyta-Chlorophyceae	238	194	101	80	46	86	171
(Chlorophyta-Desmidiaceae)	42	48	18	40	29	38	15
Chlorophyta-Charophyceae	8	4	0	0	0	9	0
Totals	343	267	145	107	61	121	351 (662)

Data Source: Modified from Herdendorf (1987) with the addition of Old Woman Creek estuary data found in the water column. This community will include many members of the other three communities that have become detached and washed into the phytoplankton. The epipelon encompasses the algae that grow in and on the soft sediments. Epipelic algae may be very important in regulating the movement of nutrients from the anaerobic sediments to the overlying water (Wetzel 1996). Many of these algae are motile flagellates that will also be found in the phytoplankton during some part of the year. The epiphyton and metaphyton refer to the algae that grow attached (epiphyton) or associated with but not attached (metaphyton) to the aquatic plants. Epilithic algae grow on rocks while episammic algae grow on sand grains or the intersitial spaces between grains. In Old Woman Creek, preliminary work has been conducted on all but the epipsammon and metaphyton algal communities.

PHYTOPLANKTON

Studies of phytoplankton in Old Woman Creek estuary (Klarer and Millie 1994b, Klarer 1989, Klarer 1983, Klarer unpublished data) demonstrate high variability in this community. Multiple peaks were observed throughout the year (Figure 7.14). The time and duration of these peaks seemed highly erratic. Despite this variability, the dominant species were similar from year to year. Through most of the year, the phytoplankton was dominated by several small *Cyclotella* species. In the later part of the spring, as water temperatures rose toward summer levels, the Cryptophytes: *Cryptomonas* spp. and *Rhodomonas minuta* var. *nannoplanctonica* became widespread. During the summer and autumn *Aulacosiera* spp., particularly *A. alpigina*, were also common in the phytoplankton. Members of the Chlorophyta and Cyanophyta were common in late summer/early fall during some years but not others.

A study examining the role of storm events on phytoplankton populations in the estuary was undertaken in 1984 after it was observed that fluctuations in population numbers often coincided with fluctuations in turbidity. This, coupled with the paucity of Chlorophyta and Cyanophyta normally dominant in Lake Erie proper, suggested that storm runoff events were a major factor in regulating estuarine phytoplankton (Klarer and Millie 1994b).

Storm water flowing through the estuary flushed out much of the existing populations, but at the same time carried nutrients into the estuary allowing the surviving populations to rapidly repopulate the estuary. In one of the sampled storms, population numbers in the lower estuary increased within two weeks of the

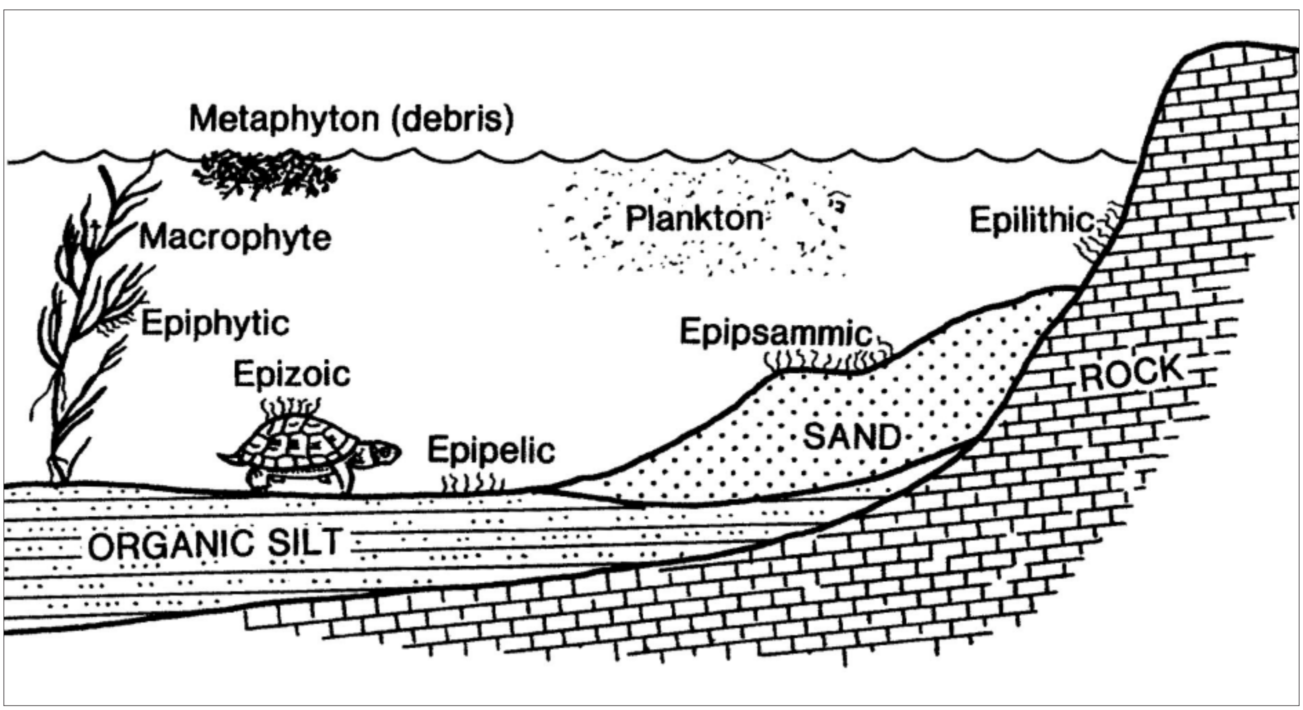


Figure 7.13. Algal communities in Old Woman Creek estuary and watershed (after Bolsenga and Herdendorf 1993).

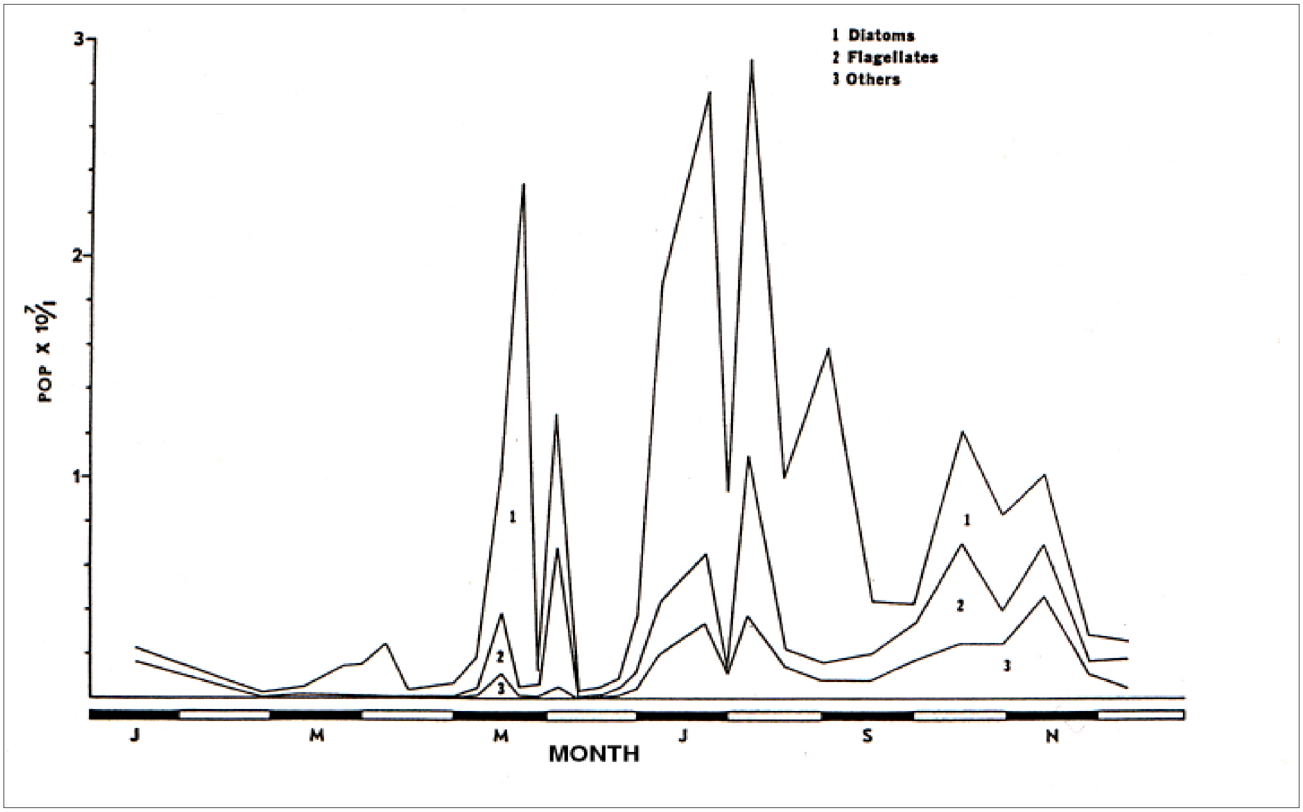


Figure 7.14. Phytoplankton populations in Old Woman Creek estuary for 1980 exhibiting multiple peaks throughout the growing season (after Klarer 1983,1989).

storm's passage to over four times pre-storm numbers; this rapid repopulation was not observed in the upper reaches of the estuary (Figure 7.15). The researchers attributed this to a lack of backwater refugia in the upper reaches of the estuary, which would have provided the surviving algae necessary for rapid recolonization.

Circumstantial evidence suggests that the agricultural chemicals applied in the Old Woman Creek watershed may be influencing both the numbers and composition of the phytoplankton. Agriculture is the dominant land-use pattern within the Old Woman Creek watershed. The short-and long-term impacts of agriculturally-derived chemicals on wetlands and their resident organisms have only recently been addressed (Krieger 1989, Krieger et al. 1989). Sieburth (1989) proposed that agricultural chemicals, when introduced into coastal embayments, potentially raise the growth ceiling of specific phytoplankton through nutrient input while killing predators, thereby allowing phytoplankton to reach maximum growth unrestrained by grazing.

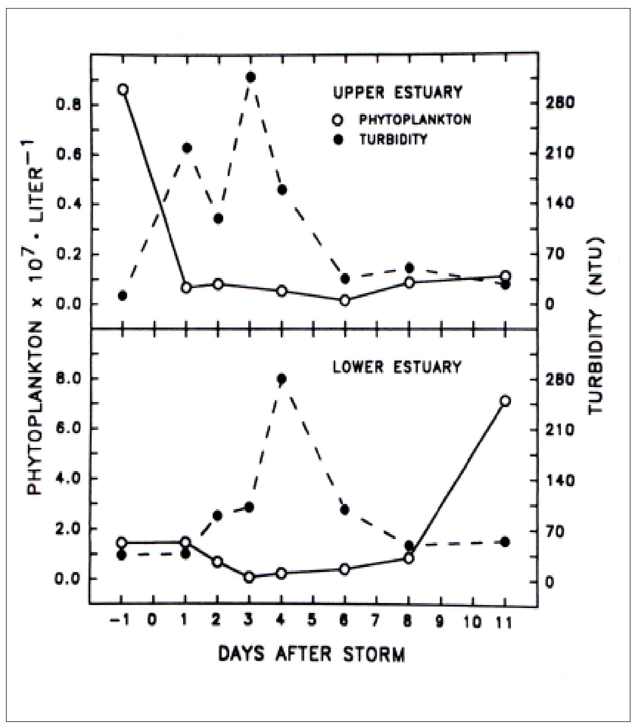


Figure 7.15. Phytoplankton standing crop in response to storm-water inflow through Old Woman Creek estuary (Klarer and Millie 1994b).

In Old Woman Creek, the flushing of the estuary would undoubtedly remove potential predators from the system. However, differential growth of phytoplankton taxa in response to agricultural chemicals might occur. Fertilizers and herbicides (particularly triazines) are routinely applied to agricultural lands within the watershed during spring planting. Although triazine residues are present in the estuary throughout the year, storm waters import a significant chemical load (Krieger 1984). Geographical races of phytoplankton and phytoplankton taxa in various physiological states display distinct growth and photosynthetic responses to differing concentrations of triazine herbicides (e.g. Millie and Hersh 1987; Millie et al. 1992)—it is highly likely that individual taxa display distinct responses as well (Hersh and Crumpton 1989). The herbicides introduced by storm waters may alter the water chemistry in Old Woman Creek enough to cause changes in the composition and physiology of the populations that potentially may recolonize the estuary. This may explain an observed selective increase of *Cryptomonas erosa* and *Cyclotella* spp. after a spring storm event, which closely followed herbicide applications in the watershed.

Klarer and Millie (1994a) examined summer and autumn phytoplankton populations in the estuary in 1992, which was a wet year with frequent storm flushing during the summer and fall, and in 1993, which was a dry year when the mouth was closed for much of the summer (Table 5.8). During July, August, and September 1992, the phytoplankton was dominated by diatoms, particularly the smaller *Cyclotella* species. The Chlorococcales (green algae containing the genera *Scenedesmus*, *Pediastrum*, and other common phytoplankton species) were present only in very small numbers. In 1993, however, when the mouth was closed for much of this 3 month period, the Chlorococcales formed a significant part of the phytoplankton. The Cyanophyta were also much more common in 1993. The lack of storms influencing the estuary permitted the estuary to become more physically stable. Under these conditions, biological interactions between the various phytoplankton species and their grazers would become more significant. When the mouth was open, there was also a much higher proportion of benthic or attached diatoms in the phytoplankton. This supports the hypothesis that periods when the mouth is open correspond to periods of increased physical instability in the estuary, in that physical processes are more important than biological ones in regulating the composition of the phytoplankton.

In the nearly two decades since the inception of the monitoring program at Old Woman Creek, Lake Erie has undergone tremendous change, both in nutrient levels and in phytoplankton composition. The massive mats of the blue-greens *Aphanizomenon* and *Anabaena*, which were so common in the 1970s, have disappeared. Filamentous diatoms and small cryptophytes are more prevalent. Nutrient levels in the waters of Lake Erie have declined. With these changes in the receiving lake as a backdrop, Klarer (1999) studied the phytoplankton in the Old Woman Creek estuary to determine if similar changes had occurred in the estuary. He reported that the total population numbers were very similar during the two 3-year periods of study (1981-1983 and 1995-1997) (Figure 7.16). The relative contribution of the various algal groups, however, was quite different during the two time periods. In both study periods, the diatoms, particularly *Aulacoseira alpigena* and various smaller *Cyclotella* species, was the dominant group through much of the spring and early summer. In the early 1980s the diatoms progressively dropped in relative importance through the year from late spring onward; while in the late 1990s, diatoms remained the dominant group through the year. In the early 1980s green algae, primarily chlorococcales such as *Scenedesmus*, *Didymocystis*, *Lagerheimia*, and *Crucigenia*, and the blue-greens, including *Merismopedia* and various *Oscillatoria* species, were increasingly more important through the summer and fall (Figure 7.17). This again can be related back to storm activity in the watershed. During the years 1981-1983 diminished rainfall in the watershed resulted in the mouth remaining closed for a major part of the summer. Rainfall amounts in 1995-1997 were adequate to keep the mouth largely open through the summer growth period. The changes reported in Lake Erie were not observed in the estuary. This study again highlighted the over-riding importance of physical processes in regulating the phytoplankton in Old Woman Creek estuary.

Wind-induced waves in the lake can push lake water into and up the estuary. Lake water is normally lower in conductivity, higher in pH, and lower in metals. In addition, the phytoplankton in Lake Erie is noticeably different from that in the estuary, therefore,

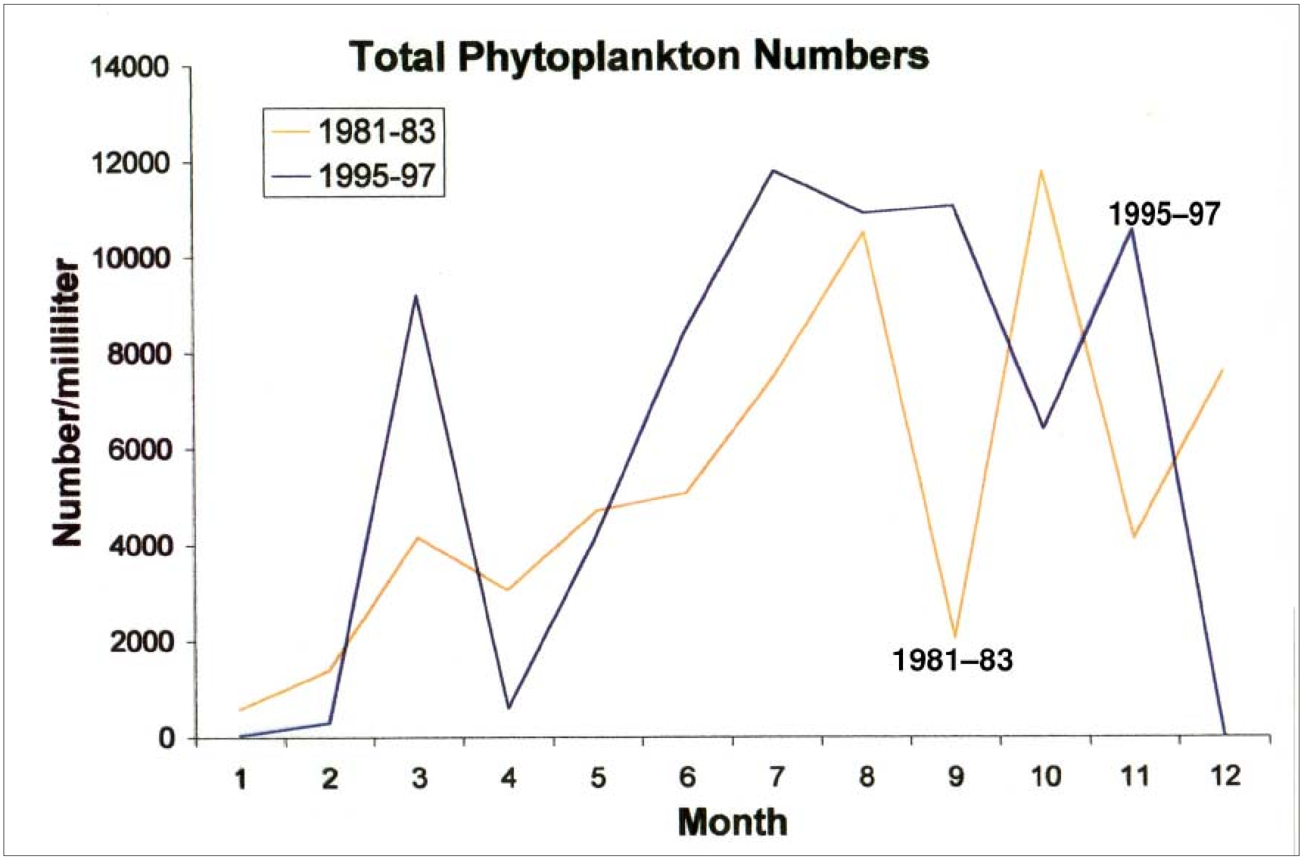


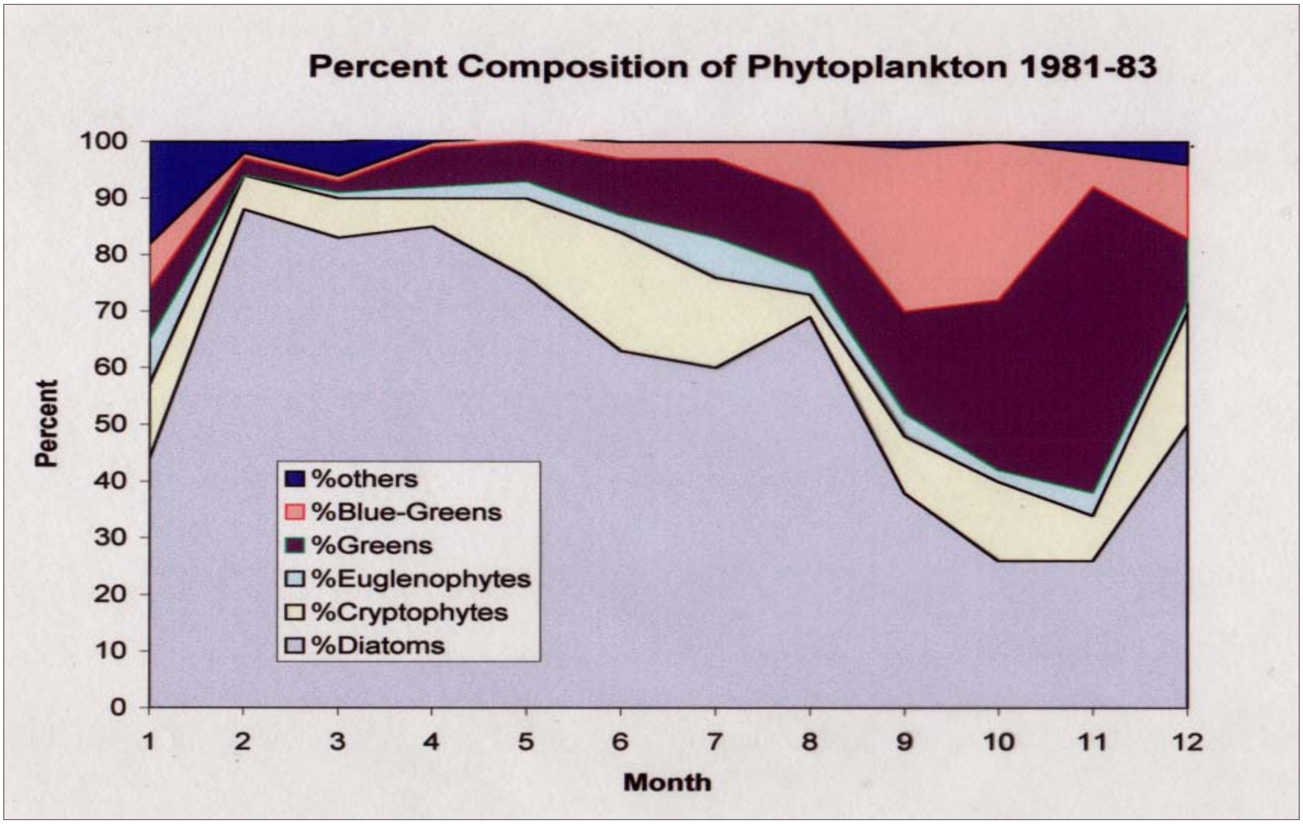
Figure 7.16. Total phytoplankton abundance in Old Woman Creek estuary during two time periods exhibiting relatively consistent numbers.

the presence of certain species such as *Stephanodiscus binderanus* or *Fragilaria crotonensis* is usually a reliable indicator of lake water intrusion.

In summary, the phytoplankton populations in the Old Woman Creek estuary seem to be storm regulated. The waters and the composition of the phytoplankton in the estuary are largely determined by storm activity, either on the lake or in the watershed. Storms and storm runoff in the estuary largely determine the numbers and species composition of the phytoplankton. With the watershed averaging more than one storm a month (see Table 4.5), the phytoplankton is normally dominated by "pioneer" species including smaller pigmented flagellates and smaller centric diatoms for much of the year. Only when storm runoff diminishes and the mouth closes does the physical habitat in the estuary become more stable. It is at these times that biological interactions between the phytoplankton itself and its grazers may become more important in determining species composition and numbers.

EPIPELON

Jensen (1992) undertook a study of the epipelon and factors that might regulate these communities in Old Woman Creek estuary. During the summer/fall sampling regime, diatom species dominated the populations, with *Nitzschia* spp., particularly *N. palea* ($4x10^5/mm^2$–August) and *N. reversa* ($1.5x10^6/mm^2$) being most common. The blue-green filamentous alga *Oscillatoria* sp. ($2.9x10^5/mm^2$) was also a dominant species at some of the sites during the late summer-early autumn period. The flagellated Euglenophytes were present in small to moderate numbers in this community. Nutrient addition studies were inconclusive. Increasing nitrate levels in the overlying waters increased diatom numbers and biovolume, but increasing phosphorus levels in the sediments also caused a marked increase in the epipelon. These contradictory results underline the need for caution when interpreting nutrient addition studies. Other factors may be influencing this community, and thus masking nutrient trends. Both shading and turbulence decreased the numbers and diversity of the epipelon.



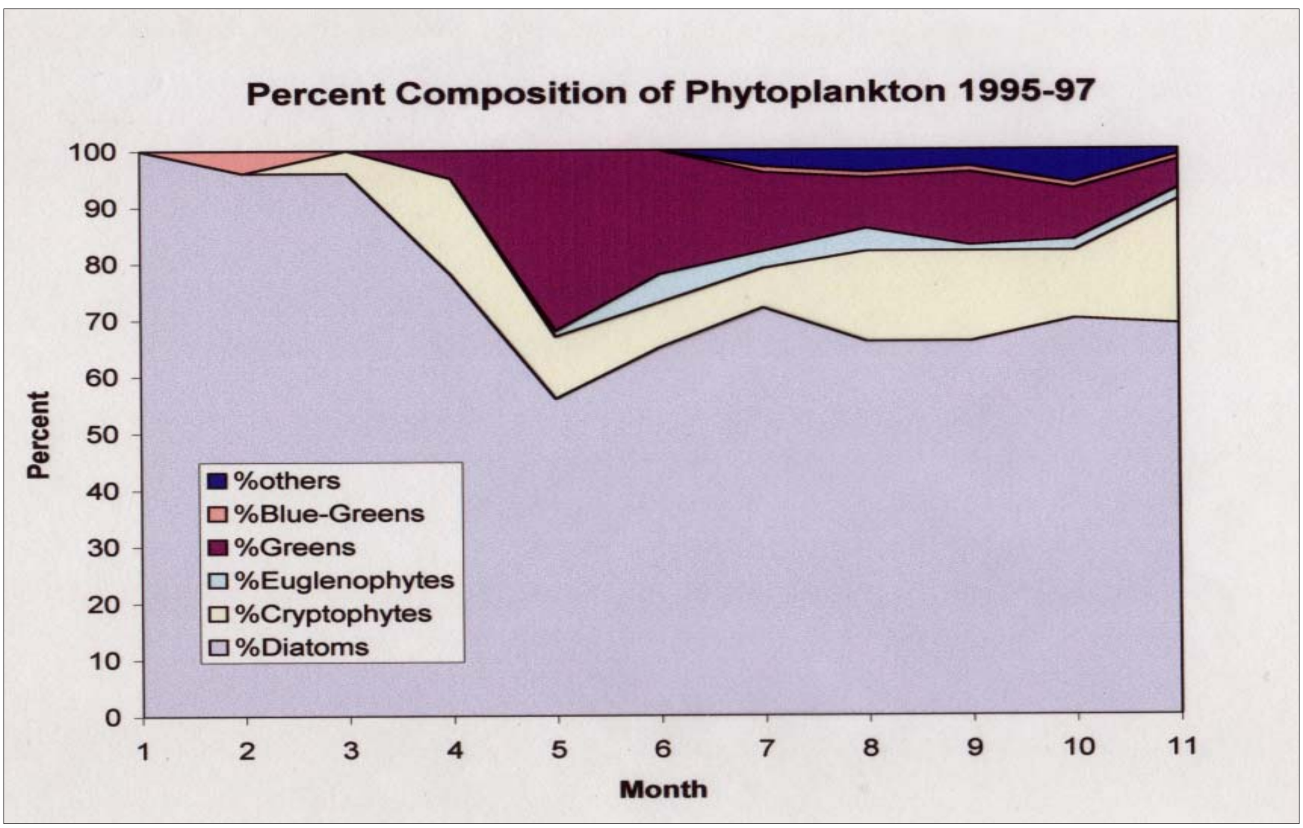


Figure 7.17. Percent composition of phytoplankton in Old Woman Creek estuary for 1981-1983 (showing autumn decline in diatom dominance) and 1995-1997 (showing continued dominance of diatoms in the autumn).

EPIPHYTON

Two studies on the epiphyton attached to the aquatic macrophytes in Old Woman Creek estuary were conducted in the early 1980s. Millie and Klarer (1980) surveyed the epiphytic algae growing attached to one algal (*Cladophora*) and nine different macrophyte hosts during June 1980. This study indicated that there was very little evidence of host specificity, but there was site specificity. In most areas of the estuary, *Gomphonema parvulum* and *Nitzschia* species (*N. filiformis*, *N. amphibia*, *N. dissipata* var. *media*, and others) dominated the epiphyton flora. In the summer of 1999, Reed (1999) studied the epiphyton growing attached to *Nelumbo* in several areas of the estuary. She reported that diatoms in the genus *Nitzschia* still dominated the epiphyton attached to *Nelumbo*, but the species included *N. palea*, which was not as prevalent in the early 1980s and *N. filiformis*, which was also a dominant in the earlier studies. The very high variability between replicates in the 1999 study suggested that environmental factors and not specific interactions between the host macrophyte and the epiphyton seem to regulate the species abundance and diversity in the epiphyton. Reed reported that there was a significant relationship between the sites and the populations in July and August of 1983 and July and August of 1999, suggesting that similar conditions resulted in similar populations. However, the populations from June 1983 were not similar to any other populations in either 1983 or 1999. The cause of this dissimilarity is not known. In June, just south of U.S. Route 6 and just south of the railroad *Thalassiosira pseudonana*, a brackish water species that has become common in Lake Erie, dominated the flora. Klarer (1981) studied the epiphyton attached to *Nelumbo* stems, both the dead stems of the previous year and the growing stems of the present year during 1980. The dead stems remained standing through the mid-spring. During this early spring period, the diatoms *Gomphonema olivaceum* and *Diatoma elongatum* and the green algae *Stigeoclonium* sp. dominated the populations growing on the dead stems. As with the earlier study by Millie and Klarer (1980), during the June period, the diatoms *Gomphonema parvulum* and *Nitzschia* species dominated the epiphyton. As the water temperatures approached summer maximum levels, the green algae *Stigeoclonium* was replaced by *Oedogonium* sp. and *Spirogyra* sp. The blue-green algae *Phormidium* sp. also became common with increasing water temperatures. In summary, the epiphyton in Old Woman Creek estuary are characteristic of a wetland that is eutrophic and slightly alkaline. The numerical dominance of both *Gomphonema parvulum*, a facultative nitrogen heterotroph, and *Nitzschia filiformis*, an obligate nitrogen heterotroph, suggest a low to moderate level of dissolved organic compounds in the water, at least through early to mid-summer.

EPILITHON

Klarer (1981) also examined the epilithon (algae growing attached to rocks) in the creek proper. In many river and stream systems, particularly in the faster moving portions, the epilithon are the dominant primary producers. In Old Woman Creek, the creek bed was dominated by the diatom *Gomphonema olivaceum* in the late winter and early spring. With increasing light levels and water temperatures, the green algae *Cladophora glomerata* became the dominant species, primarily due to its size—numerically it was never a major component of the population, but the large cell size of this algae made it the dominant in biomass. Attached to this algae was an epiphytic flora that was dominated by diatoms, particularly *Rhocosphenia abbreviata* and *Cocconeis placentula*.

PRIMARY PRODUCTIVITY IN THE ESTUARY

In a freshwater wetland system, the phytoplankton is frequently considered a minor component of the wetland system, if considered at all (Mitsch and Gosselink 1993). In two earlier data syntheses on the coastal wetlands of Lake St. Clair (Herdendorf et al. 1986) and the coastal marshes of western Lake Erie (Herdendorf 1987) the phytoplankton were considered a significant, but not dominant, source of organic carbon. Phytoplankton can have a major impact on the food web of the estuary—whether the food web is grazer-based or detrital-based (Wetzel 1983,1992). As reported by Reeder (1990), the primary source of autotrophic carbon in the Old Woman Creek estuary was the phytoplankton. This would suggest a grazer-based food web. The method used by Reeder to determine macrophyte productivity—above ground harvest—tends to underestimate the net productivity of *Nelumbo* due to the propensity of these rhizomatous perennials to translocate a significant part of the photosynthate to the underground root-rhizome system (Francko and Whyte 1999). Francko and Whyte (1999), in a later study of Old Woman Creek estuary, concluded that the macrophytes were the dominant producers in the estuary; thus, the food web would be detrital based. Although these two studies seem to contradict each other, it is very likely that each is appropriate for the particular year being studied. Macrophytes fix more carbon per unit area, on the order of 5 to 10 times more carbon (Francko and Whyte 1999); so, the relative importance of the two producers is dependent upon the percentage of macrophyte cover (Table 7.1).

From the late 1970s through the late 1980s, the estuary was most likely phytoplankton dominated; but from the early 1990s through 2001, macrophytes were dominant. When considering the food available for the next level in the food web, production measurements of *Nelumbo*—or any other aquatic macrophyte that has an extensive perennial underground rhizome or root system—must consider that a portion of the production will be translocated into the root/rhizome system and thus will be unavailable to the next food web level. Although Reeder's (1990) macrophyte production rates underestimated the available food produced because his method could not account for leaf fall prior to harvesting, Francko and Whyte's (1999) macrophyte production rates probably overestimated the food available for the next level for the reason that an unknown portion of the macrophyte production was transferred to the underground rhizome where it was unavailable for consumption by the next level of the food web.

The hypertrophic nature of the estuary is readily demonstrated with data obtained from the data loggers. The diurnal changes in oxygen and pH in the estuary (Figure 7.18) are characteristic of a system where production is very high. During the daylight hours, oxygen levels in the water rise because high primary productivity produces oxygen at a greater amount than respiration can take it up, or it can diffuse into the atmosphere. At the same time, free carbon dioxide in the water is taken up by the primary producers faster than it can be replaced by respiration and diffusion from the atmosphere, which causes the pH of the water to rise. At night, respiration reverses the trend because photosynthesis has ceased. Oxygen is taken up from the water faster than it can be replaced by diffusion from the atmosphere; thus, oxygen levels drop to very low levels with minimal concentrations occurring just prior to sunrise. At night, respiration releases free carbon dioxide back into the water faster than it can diffuse into the atmosphere, thus lowering the pH.

Data logger data also emphasize the importance of storm events in the ecology of the estuary. Figure 7-19 is a series of graphs of the data collected over a two-week period in late August to early September 1998 from a site in the upper estuary. A storm on August 25, 1998 resulted in the influx of storm water, as demonstrated by a rise in water level. This rise corresponds to both an increase in turbidity and a drop in specific conductivity. The dampening of the oxygen and pH diurnal variations after the passage of the storm (August 27 to September 1) suggests that the storm water washed away existing phytoplankton populations. About one week after the storm, the previous diurnal variations in both of these parameters returned, suggesting the re-growth of phytoplankton in the upper estuary.

Phytoplankton—Zooplankton Interaction

Havens (1991c) examined the role of zooplankton in the food web and energy flow in Old Woman Creek estuary. His work supports Reeder's contention of the importance of the phytoplankton in the estuary. Zooplankton community filtration rates here were among the highest reported in the literature with herbivores filtering up to 73% of the water column per hour. Despite this high rate there was no "clear water" period observed in the estuary. This was attributed to the very high algal productivity due to continual internal and external nutrient loading through the sampling period. These rapid rates also indicated a rapid energy flow from the phytoplankton to the zooplankton. In May and June, nauplii and small cladocerans dominated zooplankton filtration activity, but by July rotifers had become the dominant group. They maintained this dominance through August. In September the rotifers and small cladocerans were co-dominant. Through the summer and into the autumn, rotifers and the smaller cladocerans dominated the zooplankton filtration activity.

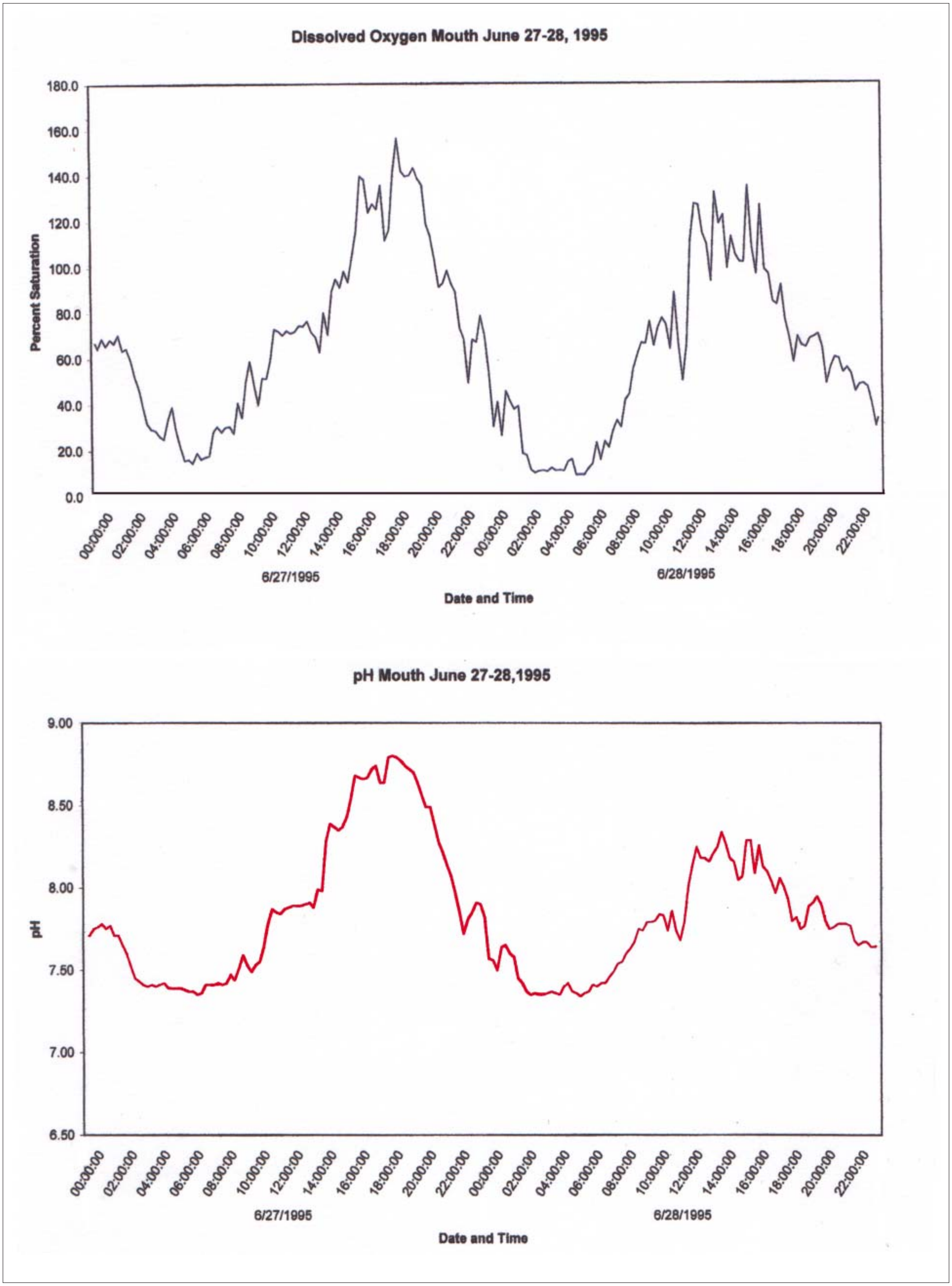


Figure 7.18. Diurnal changes in oxygen (percent saturation) and pH in lower Old Woman Creek estuary.

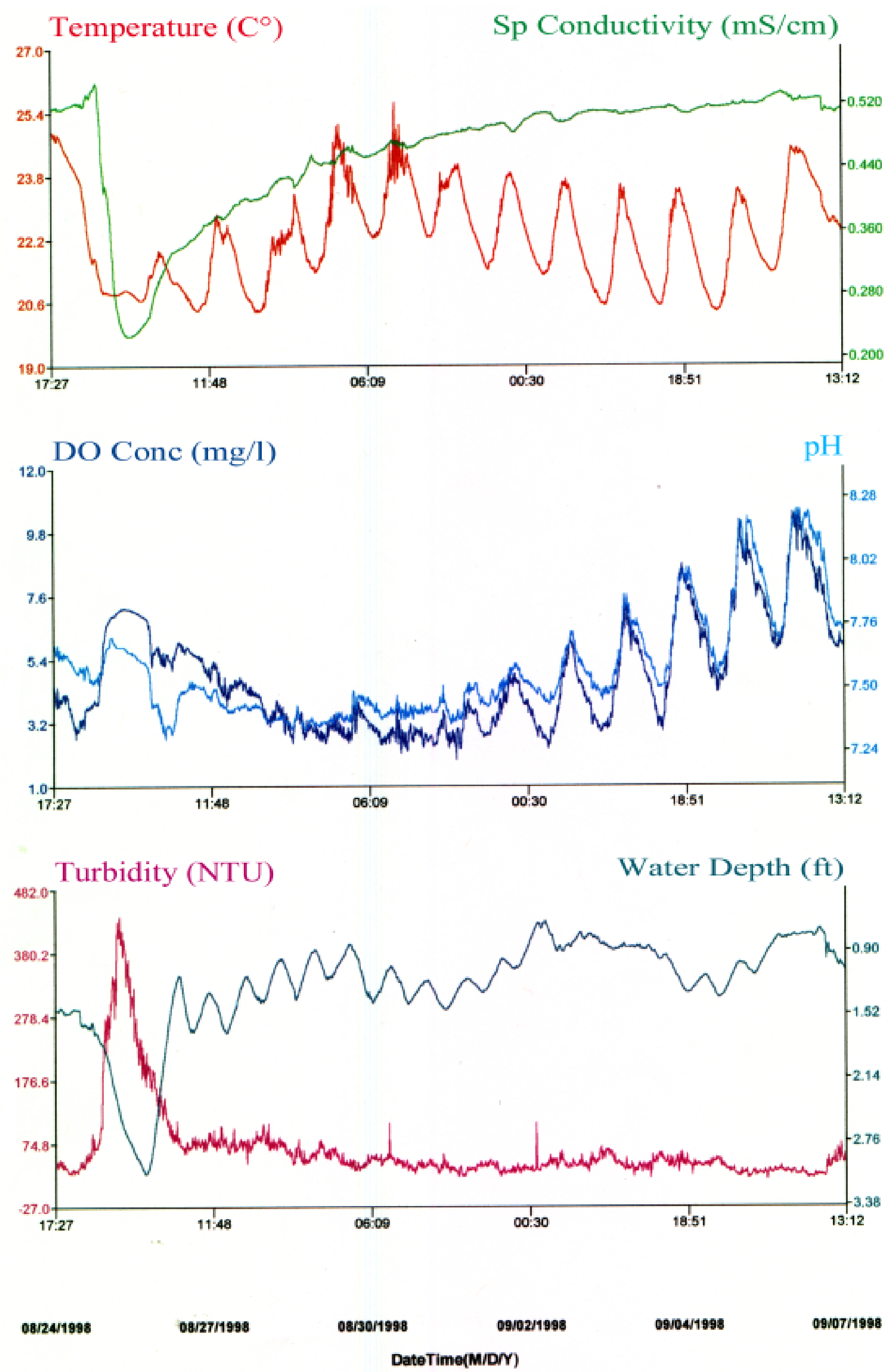


Figure 7.19. Impact of storm runoff on upper Old Woman Creek estuary during a two week period in late summer 1998.

NOTE: Upper graph—temperature (left vertical scale) and specific conductivity (right vertical scale); middle graph—dissolved oxygen (left vertical scale) and pH (right vertical scale); and lower graph—turbidity (left vertical scale) and water level (right vertical scale), water depth increases toward bottom of graph.

INVERTEBRATE ECOLOGY OF THE ESTUARY

Freshwater invertebrates are ubiquitous and often abundant members of the benthic, planktonic, periphytonic, and neustonic communities of Great Lakes estuaries and coastal wetlands. They serve an important role in the transfer of energy and materials in these habitats and also provide a major food resource for fish and waterfowl (Krieger 1992). Despite their apparent importance, comparatively little is known of the distribution and ecology of invertebrates in Great Lakes estuaries. However, in recent years a number of studies have been initiated at Old Woman Creek estuary which address the zooplankton and zoobenthos in a coastal wetland, including Miller (1982), Havens (1991a,b,c,d), Kepner and Pratt (1993,1996), Klarer (1989), Krieger (1985,1992), and Krieger and Klarer (1991,1992,1995). Terrestrial invertebrates in the Old Woman Creek watershed have received even less attention, with only three studies of limited scope, Gray et al. (1997), Phillips (1998), and Phillips and Nemire (1999). The following discussion of invertebrates in the estuary and watershed is based on the results of these investigations and several specialized studies by Bur et al. (1986), Bur and Klarer (1991), Ingold et al. (1984), and Miller et al. (1984).

ZOOPLANKTON

While some zooplankters exhibit active swimming movements that aid in maintaining vertical position, as a whole, plankton tends to settle and most plankters are unable to move against a current. As animals, zooplankton are not primary producers and are either herbivores (phytoplankton feeders), carnivores (zooplankton feeders), or omnivores (phytoplankton and zooplankton feeders). Excluding protozoans, which have been discussed earlier in this volume (Chapter 6), there are three major groups of zooplankton capable of some degree of locomotion: the rotifers, and two microcrustacean forms (cladocerans and copepods). Rotifers are classified as a distinct phylum (Rotifera), while the other two groups are in the phylum Arthropoda, class Crustacea, and subclasses Brachiopoda (cladocerans) and Copepoda (copepods).

Zooplankton in the estuary are dominated by small cladocerans and rotifers for much of the year. Many of the most important rotifer species in the estuary have previously been described as "pioneer species"—species that have rapid reproduction rates and can quickly repopulate an area (Hanazato and Yasuno 1990, Ferrari et al. 1984; as cited in Havens 1991d). The dominance of these species of rotifers and small cladocerans supports the hypothesis that the estuary is a storm driven system. The predominance of flagellates and small diatoms in the phytoplankton in the estuary should favor the dominance by the larger cladocerans, but the larger cladocerans do not have a rapid reproduction rate and so frequent flushing denudes the estuary of these organisms. Although the storms and other physical forces are critical in determining the composition of the zooplankton in the estuary, there appears to be biological interactions also affecting zooplankton distribution. There were greater numbers of the small cladocerans in the vegetated areas than in the open water areas. Havens (1993) clearly demonstrated the importance of fish predation in determining this distributional pattern.

Community Structure

The zooplankton community of Old Woman Creek estuary was compared with that of the nearshore (wave zone) of Lake Erie adjacent to the mouth of the estuary by Krieger (1985). He found that the crustacean zooplankton communities were distinctly different both in species composition and density between the upper estuary and the lake (Table 7.4). Old Woman Creek estuary is dominated by two cyclopoid copepods (*Acanthocyclops vernalis* and *Tropocyclops prasinus mexicaus*), a calanoid copepod (*Skistodiaptomus pallidus*), and two cladocerans (*Diaphanosoma birgei* and *Moina micrura*), whereas nearshore Lake Erie is characterized by a cyclopoid copepod (*Diacyclops thomasi*), a calanoid copepod (*Eurytemora affinis*), and bosminid and daphnid cladocerans (*Bosmina longirostris*, *Daphnia galeata mendotae*, and *D. retrocurva*). The lower estuary represents an ecotone (Odum 1971), in that it possesses a zooplankton community intermediate between the lake and the upper estuary. Of 40 crustacean zooplankton species identified in the lake and estuary, only 18 were found in both the lake and estuary (Krieger 1992).

The difference in zooplankton communities is also manifested in terms of the timing of life cycles. During early summer *Acanthocyclops vernalis* and *Diacyclops thomasi* are the dominant adult copepods in the estuary, and the most abundant cladocerans are

TABLE 7.4. MAXIMUM ABUNDANCE OF CRUSTACEAN ZOOPLANKTON SPECIES IN OLD WOMAN CREEK ESTUARY AND ADJACENT LAKE ERIE

	Individuals Per Liter		
	Upper Estuary	Lower Estuary	Nearshore Lake Erie
CYCLOPOID COPEPODS			
Acanthocyclops vernalis	44.4	67.0	21.7
Cyclops varicans rubellus	4.1	0.8	0.4
Diacyclops thomasi	7.0	125.5	31.0
Mesocyclops edax	1.2	2.5	8.9
Tropocyclops prasinus mexicanus	4.6	2.5	2.1
CALANOID COPEPODS			
Diaptomidae (immature copepodids)	47.3	48.0	23.0
Eurytemora affinis	0.6	2.6	17.1
Leptodiaptomus ashlandi	0.3	1.4	1.3
Leptodiaptomus minutus	–	0.3	0.4
Leptodiaptomus sicilis	–	0.2	0.6
Leptodiaptomus siciloides	0.3	0.7	0.6
Skistodiaptomus oregonensis	0.1	0.7	1.8
Skistodiaptomus pallidus	9.8	8.8	–
CLADOCERANS			
Alona quadrangularis	–	–	1.1
Alonella setulosa	–	–	1.4
Bosminidae spp. (mucronate)	19.7	54.6	76.5
Ceriodaphnia recticulata	–	0.3	–
Chydorus sp.	1.6	1.3	12.4
Daphnia galeata mendotae	0.7	1.1	20.7
Daphnia parvula	0.4	–	–
Daphnia retrocurva	1.6	1.0	15.8
Diaphanosoma birgei	19.7	20.9	2.8
Eubosmina coregoni	1.4	2.9	10.5
Ilyocryptus sordidus	0.4	–	0.5
Moina micrura	21.5	9.6	–
Pleuroxus denticulatus	0.4	0.6	–
Scapholeberis mucronata	–	0.4	

Data Sources: Krieger (1985); Krieger and Klarer (1991)

Moina micrura and several species in the family Bosminidae. By late summer the earlier dominant species decline and the cladoceran *Diaphanosoma birgei* becomes dominant in the estuary. In the wave zone of Lake Erie off the estuary mouth, the early summer dominants also include *Diacyclops thomasi* and bosminid species, but *Diaphanosoma birgei* does not become abundant. Bosminids, including *Bosmina longirostris*, attain by far the greatest abundance of all the cladocerans in the wave zone and the lower estuary (Krieger (1992). Haven (1991a) found a numerical dominance by rotifers and nauplii in May when the estuary mouth was open to Lake Erie, but cladocerans and nauplii were the most numerous in June after the mouth was closed by a sand barrier beach. Krieger (1985) noted that the periods when males and ovigerous females crustacean zooplankters were present, the egg ratios were greater in the estuary. This indicates that secondary productivity is higher in the estuary than in the nearshore waters of Lake Erie. He also concluded that depending on the number, timing, and severity of storm runoff events through the estuary, the seasonal abundances of zooplankters can be strongly reduced by flushing out the estuary.

Havens (1991a, l991d) examined the rotifers in Old Woman Creek estuary in 1990. He also found marked dissimilarities between the estuary and the adjacent Lake Erie. Total population numbers were 2 to 3 times greater in the estuary than in the lake. Within the estuary, rotifers were the most abundant group from early July through mid-September; while in the adjacent lake, they assumed numerical dominance only for a brief period in late July and early August. The most common rotifers in the estuary included *Polyarthra remata*, *Brachionus angularis*, *B. bidentata*, *B. calyciflorus*, and the predatory *Asplanchna* sp. The most common rotifers in the nearshore lake were *Keratella cochlearis cochlearis* and *Synchaeta kitina*.

ZOOBENTHOS

Zoobenthos are those animals living in or on the bed of a water body, be it stream, estuary, or lake (Figure 7.20). Two related groups of animals are the periphytic invertebrates, which live on the submerged surfaces of aquatic plants, and the neuston, the community of small animals such as water striders that

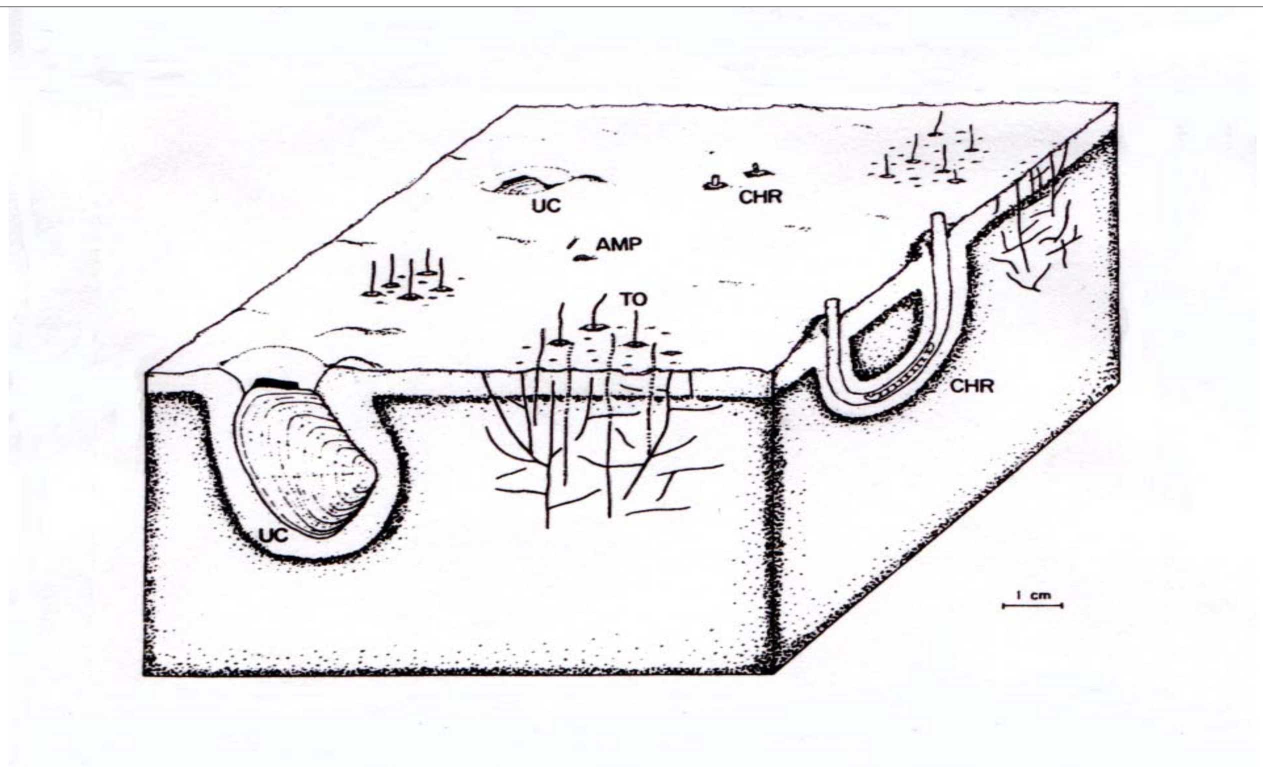


Figure 7.20. Life positions of macrobenthos in Old Woman Creek estuary (from Fisher 1982). NOTE: AMP–amphipods; CHR–chironomids, TO–tubificid oligochaetes; UC–unionid clams

TABLE 7.5. CLASSIFICATION OF BENTHIC INVERTEBRATES OF OLD WOMAN CREEK ESTUARY AND WATERSHED AND THE ADJACENT NEARSHORE WATERS OF LAKE ERIE

KINGDOM PROTISTA (PROTOZOA)

PHYLUM SARCOMASTIGOPHORA
Subphylum Mastigophora
- Class Dinoflagellata
- Class Phytomastigophora
- Class Euglenea
- Class Zoomastigophora

Subphylum Sarcodina
- Class Lobosa
- Class Filosa
- Class Granuloreticulosa
- Class Heliozoa

PHYLUM CILIOPHORA
- Class Kinetofragminophora
- Class Oligohymenophora
- Class Polyhymenophora

KINGDOM ANIMALIA

PHYLUM PORIFERA
- Class Demospongiae (horny sponges)

PHYLUM CNIDARIA
- Class Hydozoa (hydras)

PHYLUM PLATYHELMINTHES
- Class Turbellaria (flatworms)

PHYLUM GASTROTRICHA
PHYLUM ROTIFERA (rotifers)
PHYLUM NEMATODA (roundworms)
PHYLUM MOLLUSCA
- Class Gastropoda (snails)
- Class Bivalvia (clams)

PHYLUM ANNELIDA
- Class Hirudinea (leeches)
- Class Oligochaeta (segmented worms)

PHYLUM ARTHROPODA
- Class Arachnida (spiders & water mites)
- Class Crustacea
  - Subclass Branchiopoda
    - Order Cladocera (water fleas)
  - Subclass Ostracoda (seed shrimp)
  - Subclass Copepoda (water-hoppers)
    - Order Harpacticoida
    - Order Cyclopoida
  - Subclass Branchiura (fish lice)
  - Subclass Malacostraca
    - Order Isopoda (sow bugs)
    - Order Amphipoda (scuds)
    - Order Decapoda (crayfishes)
- Class Insecta
  - Order Collembola (springtails)
  - Order Ephemeroptera (mayflies)
  - Order Odonata (damselflies & dragonflies)
  - Order Plecoptera (stoneflies)
  - Order Hemiptera (true bugs)
  - Order Neuroptera (nerve-wing insects)
  - Order Coleoptera (beetles)
  - Order Diptera (true flies)
  - Order Trichoptera (caddisflies)
  - Order Leptopitera (butterflies & moths)

PHYLUM TARDIGRADA (water bears)
PHYLUM BRYOZOA (bryozoans)

live in association with the surface film of water bodies. Because the benthic invertebrate community represents a major food resource for fishes, impacts the plankton community through various feeding activities, participates in the decompositional pathways, and in turn is influenced by the presence of hydrophyte beds, this community is a major link in the overall ecology of the Old Woman Creek estuary. A zoobenthos study was undertaken by Krieger and Klarer (1992,1995) with two objectives: (1) to determine the relative species richness of benthic and periphytic invertebrates in open water and in aquatic plant beds within the estuary and (2) to compare the benthic community of the estuary with that of the upland creek and the adjacent nearshore of Lake Erie. The results of their investigations are summarized in the following sections.

Community Structure and Species Richness

Altogether 144 taxa of benthic invertebrates (Table 7.5) were identified from Ekman dredge and 7.5 cm diameter core samples of sediment obtained throughout the estuary as well as from leaves, stems and tubers of aquatic plants. Samples were taken approximately every two months for a period of one year. Of the nine phyla found in the estuary, 38% were insects, 22% were crustaceans, and 20% were oligochaete worms. The number of taxa found in samples taken within the American lotus beds (*Nelumbo lutea*) exceeded the number of taxa present in open water samples by about 1.5 times at the end of the growing season. Invertebrate densities on lotus stems were somewhat less than 20,000 individuals/m^2, whereas sediments typically had 100,000 or more individuals/m^2.

The most widespread species was the naidid worm *Nais variabilis*, which was found both in the sediment and on lotus plants. Immature tubificid worms were widespread throughout the estuary sediments, but were not found on plant surfaces. Although never abundant, turbellarian flatworms were widespread in the sediments and on plants. The overwintering stage of bryozoans (statoblast) was very abundant in many samples as was the ephippium capsule of cladocerans. The cladoceran *Ilyocryptus sordidus* was widely distributed and abundant during the fall and spring, but infrequent in the winter. Nematode roundworms were found in most habitats, at times in considerable abundance.

Among the insects, ceratopogonid flies were the most widespread in sediments, but not usually very abundant. The chironomid *Glyptotendipes* sp. occurred in sediments and on plants, but only in the fall and winter; whereas, *Tanytarsus* sp. was widespread in sediments mainly in the winter and spring. Corixid water boatmen were common in all habitats during the summer and fall, but absent in winter and spring. Dragonfly and damselfly nymphs were found throughout the estuary, but in low numbers. Young nymphs of capniid stoneflies were particularly common in the open water sediments and in the flooded creek channel comprising the upstream end of the estuary.

Other relatively common taxa that were restricted entirely or primarily to particular benthic habitats include all the snails—with the exception of the large Japanese snail (*Cipangopaludina japonica*) which always associate with aquatic plants. Only two live zebra mussels (*Dreissena polymorpha*) were collected, one in a sediment sample and the other on a lotus leaf, and only in the fall. Krieger and Klarer (1992) speculated that this may indicate that they do not survive over winter in the shallow habitat of the estuary. Unionid clams, although widespread, were sparse and restricted to the sediments.

Three relatively rare insects, the microcaddisfly *Agraylea* sp. and two beetle larvae (a chrysomelid and a scirtid), were found only in the sediments of lotus beds. These taxa typically live on or near vascular hydrophytes. *Agraylea* feeds on attached filamentous algae; chrysomelid larvae pierce the lotus plant to obtain air directly from the inside air spaces (lacunae); and scirtid marsh beetle larvae typically remain just below the surface film and feed on decaying leaves and other vegetation. The epiphytic invertebrate community living on a lotus stem in October consisted of six taxa: the chironomid larvae *Glyptotendipes* sp. (9,944/m^2) and *Cricotopus* sp. (5,136/m^2); naidid oligochaetes *Nais variabilis* (1,964/m^2), *Nais pardalis* (927/m^2), and *Dero nivea* (55/m^2); and ceratopogonid fly larvae (55/m^2).

Seasonally, the neuston comprises a highly visible component of the Old Woman Creek estuary invertebrate fauna. Krieger and Klarer (1992) found large aggregations of gyrinid and hydrophylid beetles, as well as corixid water boatmen, in the late summer and autumn.

Because of seasonal life cycles, several benthic taxa are only present or especially abundant during a particular season. Among the oligochaete worms, several species of *Pristina* were found only in the fall, whereas two species of *Vejdovskyella* were present only in the spring. Likewise, leeches were only collected in the fall and tardigrade water bears were only abundant during the winter and spring. Some midges were also seasonal: *Dicrotendipes* sp. was found only in the fall, *Glyptotendipes* sp. in the fall and winter, and *Hydrobaenus* sp. in the winter.

On an annual basis, the benthic community of Old Woman Creek estuary is dominated numerically by nematodes, tubificid and naidid worms, tardigrades, ceratopogonids, cladocerans (particularly *Ilyocryptus sordidus*), and chironomids. Overall, the plant beds contained a greater species richness than the open water areas. Essentially, the sediment within the plant beds contained almost all of the taxa found in the open water sediment as well as several species associated specifically with hydrophytes.

Comparison of Estuary, Creek, and Lake Communities

Krieger and Klarer (1992) concluded that the benthic community of Old Woman Creek estuary is distinct from the benthic communities of the upland creek and adjacent Lake Erie. They found the presence of an ecotone (a narrow and fairly sharply defined transition zone between two communities) at the upper end of the estuary where the zone is restricted to the flooded Old Woman Creek channel. In this channel the larvae of the riffle beetle *Dubiraphis* sp., which was characteristic of the upland creek bed, were present throughout the year in relatively small numbers, whereas, these larvae were essentially absent in the remainder of the estuary. Likewise the early instars of capniid stoneflies were frequent in the upstream pools and the flooded upper channel of the estuary, but were rare elsewhere in the estuary. *Ilyocryptus sordidus*, which was dominant in the open estuary, was present in low numbers in the upper end of the estuary and was usually absent in the upland creek bed.

Correspondingly, the nearshore wave zone of Lake Erie along the barrier beach at the mouth of Old Woman Creek estuary possesses a distinct macroinvertebrate community. Here, the shifting sands create a harsh environment resulting in a smaller abundance of the same groups which dominate the more offshore, less sandy, softer sediments of the nearshore zone of the lake. The dominant members of the lake community include the tubificid oligochaetes, especially *Limnodrillus* spp.; chironomid larvae, primarily *Procladius* sp., *Chironomus* spp., and *Cryptochironomus* sp.; sphaeriidae clams; ostracods; and nematodes. Each of these taxa were at least occasionally found in the estuary, except sphaeriidae clams which were absent.

Ecological and Tropic Interactions

Krieger and Klarer (1992) also tested the hypothesis that differences in the benthic invertebrate community were the result of differences in water depth and thus the frequency of subaerial exposure of the estuary bed (i.e. water level lowered to the point where sediments were exposed to the air). Their study showed no evidence of differences in community structure along the depth gradient in the estuary, even though some of the sampling sites were exposed up to 31% of the time. However, during these periods of dewatering the sediments appeared to remain moist. Despite occasional freezing at the sediment surface in winter, the invertebrate community apparently survived the conditions without demonstrable effect. The investigators speculated that the invertebrate community may have been adversely affected by exposure, but recovery via recolonization or hatching of eggs or cysts may have been too rapid to be detected.

Also, physical and chemical differences in the water column and sediments appear to have little influence on the benthic community structure in the broad expanse of the estuary; physiochemical variations never reached limits to survival and reproduction of the major invertebrates in the open estuary. Strong water currents during periods of storm runoff, however, may be responsible for the ecotonal nature of the flooded creek channel comprising the upper end of the estuary. Under these conditions, invertebrates are most likely washed from their typical stream habitats and deposited downstream where the water velocity is lower.

The interactions of the many benthic invertebrate taxa with each other and the vertebrates, aquatic plants, and decompositional communities constitute an important aspect of the Old Woman Creek estuary ecology. Knowledge of the seasonal distribution and abundance of these taxa is an essential foundation for understanding these interactions. The study by Krieger and Klarer (1992) suggests that a complex food web exists in the estuary. However, few benthic invertebrates appear highly specialized in their food habits. Most carnivores feed on a variety of prey, detritivores often ingest microinvertebrates and algae along with detritus, and many invertebrate "scrapers" and "grazers" are omnivores, nonselectively ingesting whatever is present on the substrate and unable to escape. Table 7.6 lists the trophic categories of the major benthic invertebrates identified from Old Woman Creek estuary. Unfortunately, knowledge of invertebrate energetics and materials cycling in Great Lakes estuaries and coastal wetlands is limited and determining the exact pathways of energy and material flow through the food web of Old Woman Creek estuary can only be ascertained by further observations.

FISH AND REPTILE ECOLOGY OF THE ESTUARY

FISH COMMUNITY

The diversity of species present in Old Woman Creek reflects typical fish populations of estuarine areas along Lake Erie's southern shore. The importance of these coastal areas for the production of commercial, recreational, and forage fishes has been documented by Trautman (1957,1981) and Hartman (1973). About 40 species of Lake Erie fish need "marsh-like" habitat to spawn and raise young (Johnson 1989). Hoffman (1985) found that the large numbers of young of the year (YOY) and juvenile fishes captured in the estuary with test nets reflect the importance of the Old Woman Creek estuary as a nursery and spawning area.

TABLE 7.6. TROPHIC CATEGORIES OF BENTHIC INVERTEBRATES FOUND IN OLD WOMAN CREEK ESTUARY

Carnivores	Detritivores	Herbivores	Omnivores	Parasites
Ciliophora	Oligochaeta: *Nais*	Ciliophora	Rotifera	Dtera: *Parachironomus*
Turbellaria	Tubificdae	Naididae	Bryozoa	Hirudiea: *Helobdella* &
Naididae:*Chaetogaster*	Hirudinea: Glossiphoniidae	Tubificidae	Coleoptera:	*Plaobdella*
Hirudinea: Glossiphoniidae	Turbellaria	Bryozoa	Elmidae	Hdrachnidia larvae
Bryozoa	Bryozoa	Nematoda	Hydrophillidae: *Tropisternus*	
Nematoda	Nematoda	Rotifera	Scirtidae: *Cyphon*	
Rotifera: *Asplanchna*	Coleoptera:	Tardigrada	Diptera:	
Coleptera:	Scirtidae: *Cyphon*	Coleoptera:	Ephydridae	
Dytiscidae	Hydrophilidae: *Helophorus*	Chrysomelidae	Chironomidae:	
Gyrinidae	Halipiidae: *Peltodytes* adults	Hydrophillidae: *Loccobius* &	*Chironomus*	
Tropisternus larvae	Diptera:	*Tropisternus* adults	*Cladoplema*	
Halipiidae: *Peltodytes* adults	Ephydridae	Scirtidae: *Cyphon*	*Dicrotendipes*	
Diptera:	Tipulidae	Halipiidae: *Peltodytes* adults	*Endochironomus*	
Ceratopogonidae	Chironomidae:	Diptera:	*Glyptotendipes*	
Chaoboridae	*Chironomus*	Ephydridae	*Parachironomus*	
Ephydridae	*Endochironomus*	Tipulidae	*Polypedilum*	
Chironomidae:	*Glyptotendipes*	Chironomidae:	*Stictochironomus*	
Cryptochironomus	*Polypedilim*	*Endochironomus*	*Tribelos*	
Parachironomus	*Stictochironomus*	*Glyptotendipes*	*Tanytarsini*	
Polypedilum	*Tribelos*	Corixidae: *Sigara*	*Hydrobaenus*	
Coelotanypus	Plecoptera: Capniidae	Trichoptera: *Agraylea*	*Procladius*	
Procladius	Amphipoda		*Tanypus*	
Tanypus	Cladocera: Chydoridae &		*Heterotrissocladius*?	
Hemiptera: *Belostoma*	Macrothricidae		Ephemeroptera	
Corixidae: *Trichocorixa*	Copepoda: Cyclopoida &		Corixidae:	
Neuroptera: *Sialis*	Harpacticoida		young *Trichocorixa*	
Odonata	Isopoda		*Sigara*	
Copepoda: Cyclopoida	Ostracoda		Trichoptera, *Agraylea*	
Hydrachnidia:	Gastropoda		Amphipoda	
deutonymphs, adults	Bivalvia		Cladocera	
			Copepoda: Calanoida,	
			Cyclopoida &	
			Harpacticoida?	
			Isopoda	
			Ostracoda	
			Gastropoda	
			Bivalvia	

Data Sources: Balcer et al. (1984), Merritt and Cummins (1984), Pennak (1989), Thorp and Covich (1991), Krieger and Klarer (1992)

Environmental changes, both natural and man-made have resulted in changes in fish species occurrence over the past decade. Siltation, turbidity, wave action, changing water levels, toxic substances, and increased development have all contributed to the demise of coastal marshes along Lake Erie (Raphael and Jaworski 1978). Likewise, Old Woman Creek has experienced some of these changes—particularly during high water years—which were especially detrimental to emergent plants. Agricultural activities throughout the watershed and removal of upland forests have contributed to the increased turbidity and siltation in streams, resulting in unfavorable conditions for fishes that require clear water and clean sand or gravel substrates for spawning (Trautman l957).

Northern pike populations of Old Woman Creek in the 1950s were productive enough to permit the Ohio Division of Wildlife to remove some for stocking in other areas of Ohio. Old Woman Creek was reportedly one of the most productive fishing spots for crappie and largemouth bass as well as northern pike along Lake Erie (Miller 1957). Although the more tolerant crappie and largemouth bass still are quite numerous, few northern pike have been captured in recent times. Seining has produced no northern pike. However, electroshocking in the 1984 season produced two juvenile pike, and one adult was captured in a gill net.

Ohio Division of Wildlife surveys from 1970-1980 recorded 4 pike captured in fyke nets set in Old Woman Creek. Although the entire Lake Erie northern pike population is low (Trautman 1981b), the only obvious reason for such a drastic decline in abundance over 30 years seems to be loss of appropriate habitat. Old Woman Creek was historically in the "prairie" type marshlands of Ohio, and its once heavily vegetated waters offered ideal spawning and rearing habitat that attracted great numbers of pike during their early spring spawning runs. The pike is not the only species of fish to succumb to habitat changes in Old Woman Creek. Hoffman (1985) reported abundant populations of bowfin, smallmouth bass, buffalofish, longnose gar, and Northern fathead minnows. Recent sampling has not produced any buffalofish and very few gar, bowfin and fathead minnows. The low numbers of these species suggest some type of environmental change not favorable to these species.

Johnson (1989) suggested that natural wetlands cover such a relatively small area along the Lake Erie coast and are so readily destroyed or degraded, that controlled marshes may represent the last high quality coastal marsh resource remaining on the lake. Thus, the fate of northern pike, and other species sensitive to environmental changes is tenuous. From 1970-1980, 327 black bullheads and 45 brown bullheads were captured in fyke nets set by the Division of Wildlife. Sampling conducted in Old Woman Creek by Thibault (1985) in 1983 and 1984 shows a complete reversal in the species ratio, with 111 brown bullheads captured and only 10 black bullheads recorded. Trautman (1981) found that black bullhead tend to use small, silty impoundments, while brown bullhead tend to prefer deeper waters similar to those of the Ohio River and western Lake Erie. Old Woman Creek does not follow this trend. The shallow, heavily silted, turbid waters of the estuary appear to favor the brown bullhead. Perhaps the estuary's close proximity to Lake Erie and seasonal access may have permitted the brown bullhead to establish an abundant resident population.

The orangespotted sunfish was first taken in the tributaries of the Sandusky Bay in 1948 (Trautman 1981b). This invader from the west is becoming abundant in the marshes and small streams of southern Lake Erie due to their tolerance to high silt and turbidity. The first record for orangespotted sunfish in Old Woman Creek was in 1981, and this species of sunfish has been captured in each successive year. Numbers have increased, and the orangespot is now very common in the estuary (Hoffman 1985). Another invading species, the white perch, was first captured in Old Woman Creek estuary in July, 1980. Considerable numbers were recorded at the mouth of the estuary in the company of white bass during spawning months. YOY and 1st year white perch were numerous in late summer months. Trautman (1981) suggests that new invaders first become overly abundant, then experience a decline as the species becomes a part of the resident fish fauna.

The gizzard shad is an important forage fish in Lake Erie (Bodola 1966). The shad, while playing an important role as food for many sport and commercial species, grows to a large size so rapidly that they become unusable to predators (Scott and Crossman 1973). Gizzard shad captured from 1981-1984 in Old Woman Creek were about 95% YOY and 1st year class fishes (Hoffman 1985, Thibalt 1985). The protected, shallow waters of the estuary and the abundance of phytoplankton and algae offer a nursery situation which is very favorable for shad. Gizzard shad in the larval and juvenile stages make up the largest percentage of the diet in piscivorous fishes in Old Woman Creek estuary. During the time immediately following a major storm event large numbers of shad are killed and are carried out into the lake. Researchers have noted on several occasions that during these times, predatory fish such as the white bass, and several species of gulls congregate offshore to feed (Hoffman 1985).

Little is known about the effects of the shifting barrier beach at the mouth of the estuary on anadromous species such as trouts and salmons. Continued monitoring may show whether seasonal opening and closing of the estuary mouth hampers fish attempts to enter spawning habitat. In nearby Cranberry Creek, where the mouth remains open year around, steelhead trout and coho salmon are frequently caught by sport fishermen during spring spawning runs (Hoffman 1985).

Thibault (1985) found that the estuary of Old Woman Creek appears to have a fish fauna of its own and is probably an established environment for a number of species of fish. A gradient in environments sustains a gradient in fish species varying from more open water (lacustrine) to more flowing water (riverine) forms. Traditional Lake Erie fishes of commercial importance frequent the estuary erratically and are not a significant component of the fauna. However, these fishes episodically reproduce in the estuary or use it for a nursery.

Thoma (1999) concluded that Old Woman Creek estuary was severely impacted by sedimentation from the watershed, especially that resulting from highway construction. He found that the estuary was characterized by a fish community of pollution-tolerant taxa and non-indigenous species. The low density of the fish community was in contrast to the historic fish communities which contained significant populations of northern pike, largemouth bass, other sunfish, and native minnows.

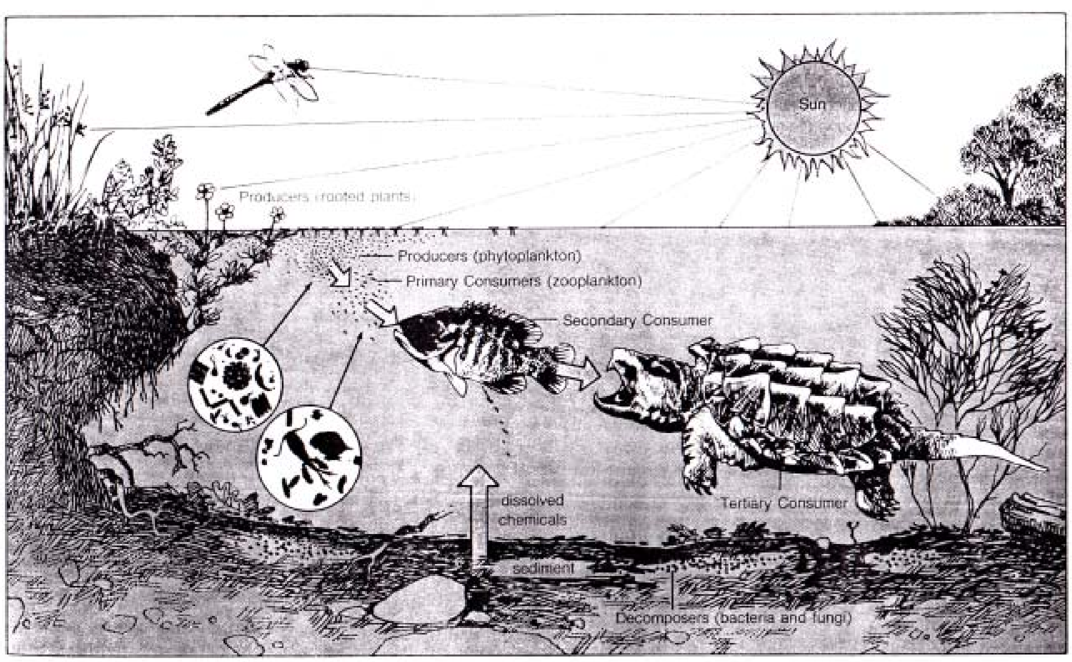


Figure 7.21. Aquatic food chain in Old Woman Creek estuary (ODNR).

SNAPPING TURTLES

The snapping turtle (*Chelydra serpentina*) is the largest freshwater turtle in the Great Lakes region, growing to lengths of over 70 cm (average shell 28 cm long) and weights of more than 20 kg (average 5 to 16 kg). Conant and Collins (1991) describe them as "ugly both in appearance and disposition." They have a large head, heavy neck, stout legs, and a long, saw-toothed tail that are not covered by the rough, dark brown carapace (upper shell). The small, cross-shaped plastron (lower shell) allows free action of the legs and head, and is dark brown to yellow in color (Morgan 1930). Snapping turtles inhabit permanent marshes and embayments of Lake Erie and its tributary streams. Bernhardt (1985) reported them as common in Old Woman Creek estuary, particularly south of Star Island. Of 21 specimens noted in his survey (82% females), the carapace length ranged from 18 to 40 cm, with two individuals exceeding 15 kg in weight. One female was extremely pale in color and had a length of 31 cm and a weight of 11 kg (Figure 1.7).

In addition to their aquatic habitat, snapping turtles are commonly found on land near a water body or exploring adjoining fields (Morgan 1930). They rarely bask on logs as do most other freshwater turtles; in shallow water they often burrow under the mud with only their eyes and nostrils showing (Conant and Collins 1991). However, snapping turtles are good swimmers, capable of covering 3 km in several hours (Behler and King 1979). When catching food, the head darts forward, mouth often agape, and powerful jaws snap suddenly (Figure 7.21). Although their movements are normally slow, the head can strike with lightning speed. Snapping turtles are seldom ill-tempered when encountered in the water, although on land they are aggressive and sometimes vicious. Their musk-like odor is also offensive (Klots 1966). They are omnivorous and seek food both night and day. Food items include fish, reptiles, frogs, insects, crayfish, ducklings, small mammals, carrion, and large quantities of aquatic plants (Buck 1955). In winter, snapping turtles hibernate in the mud bottom of the estuary, emerging from their retreats in April.

ECOLOGICAL MODELS

Heath (1992) constructed a conceptual model of nutrient dynamics for Old Woman Creek based on a synthesis of research investigations conducted at the Research Reserve (Figure 7.22). His model emphasizes the importance of sediment–water interactions owing to the shallowness of the estuary. Microbial activity in the water column, at the sediment–water interface, and within the sediment is considered intense because of the high temperatures resulting from the shallowness. The water column is treated without vertical structure because complete mixing is frequent, providing sediment resuspension and wide diurnal variations in dissolved oxygen at the sediment surface (Figure 5.13).

The model is designed to represent the estuary during a period of relatively low flow, as occurs after formation of the barrier beach. The model is also built on the assumption that after formation of the barrier beach biotic nutrient assimilation becomes progressively more significant during the passage of incoming nutrients through the estuary wetlands; although sedimentation may also represent a major sink for incoming nutrients. When the barrier beach is open and flow through the wetlands occurs, nutrient loss from the water column is largely due to sorption on sediment particles.

Mitsch and Reeder (1991) and Mitsch (1992b) developed a series of hierarchical models to simulate ecological processes in Old Woman Creek estuary. Figure 7.23 shows a model of the estuary with details of some of the processes in a wetland which contribute to its nutrient retention capability. Plant uptake, both by plankton and macrophytes, sedimentation, and resuspension are probably the most significant processes involved in the wetland retaining and releasing phosphorus. This conceptual model was developed into a simulation model based on knowledge of the cycling of phosphorus and energy in wetland ecosystems. Unique to this wetland model is the interaction of Lake Erie with the wetland. The model was divided into three submodels for simulation purposes.

A hydrology submodel of the simulation model is designed to depict the hydrologic budget of Old Woman Creek wetland with the only stated variable for this submodel being the volume of water in the estuary. Factors affecting the volume of water in the marsh include rainfall, watershed inflow, evapotranspiration, and exchange with Lake Erie. The availability of inflow data, fairly good data on evaporation, and knowledge of the hydrologic forcing functions in the wetland allowed the development of an accurate hydrologic budget and model. An important part of the hydrodynamics is the timing of an ephemeral barrier beach on the wetland outflow.

A primary productivity submodel includes the state variables macrophyte biomass and plankton biomass. These are both a function of sunlight, with the major losses being respiration and sedimentation. The productivity submodel is linked to the hydrology submodel in two ways. First, plankton are exported to Lake Erie when water from the wetland flows into the lake and the beach is open. This assumption is consistent with the field data. Second, macrophytes are assumed to be more abundant when water levels are lower, and less abundant when water levels are higher. This is based on observations of other Lake Erie coastal marshes (Herdendorf 1987). Field measurements of gross primary productivity as measured in Old Woman Creek estuary were in general agreement with model simulations. Using chlorophyll *a* as a calibration variable, the model and field data were found to be in agreement (within one standard deviation) 78% of the time. Given the differences in the two field measurements and the variability of energy/chlorophyll ratios in aquatic systems (Vollenweider 1974), the model accurately predicted seasonal patterns of productivity and biomass.

A phosphorus submodel was coupled with both the hydrology and primary productivity submodels and is incapable of running simulations without input from these submodels. This submodel utilizes one phosphorus storage in the waters of the wetland and another in the sediments, with linear pathways between the two. The phosphorus submodel includes a sedimentation pathway as defined for shallow lakes by Henderson-Sellers (1984) with an average settling velocity of 0.03 m d^{-1}. Calibration was done by varying the resuspension coefficient until the model predicted phosphorus concentration results similar to field data.

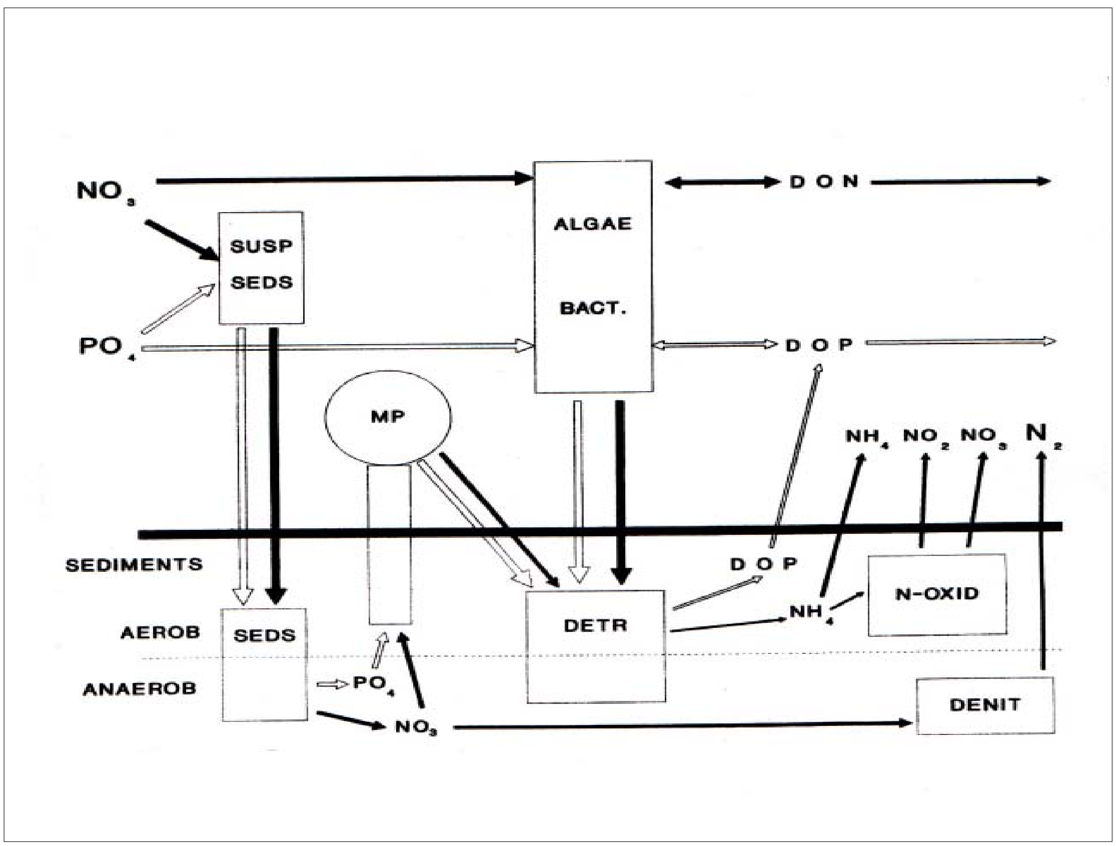


Figure 7.22. Conceptual model of nutrient dynamics in Old Woman Creek estuary.

NOTE: Nitrogen flux in solid arrows; phosphorous flux in open arrows; particulate quantities in boxes; dissolved quantities unboxed; SUSP SED—suspended sediment; SEDS—sediments, aerobic sediments above dashed line and anaerobic sediments below; water column above heavy solid line; MP—rooted macrophytes; DETR—detritus; N–OXID—nitrogen oxidizing bacteria; DENIT—denitrifying bacteria (Heath 1992).

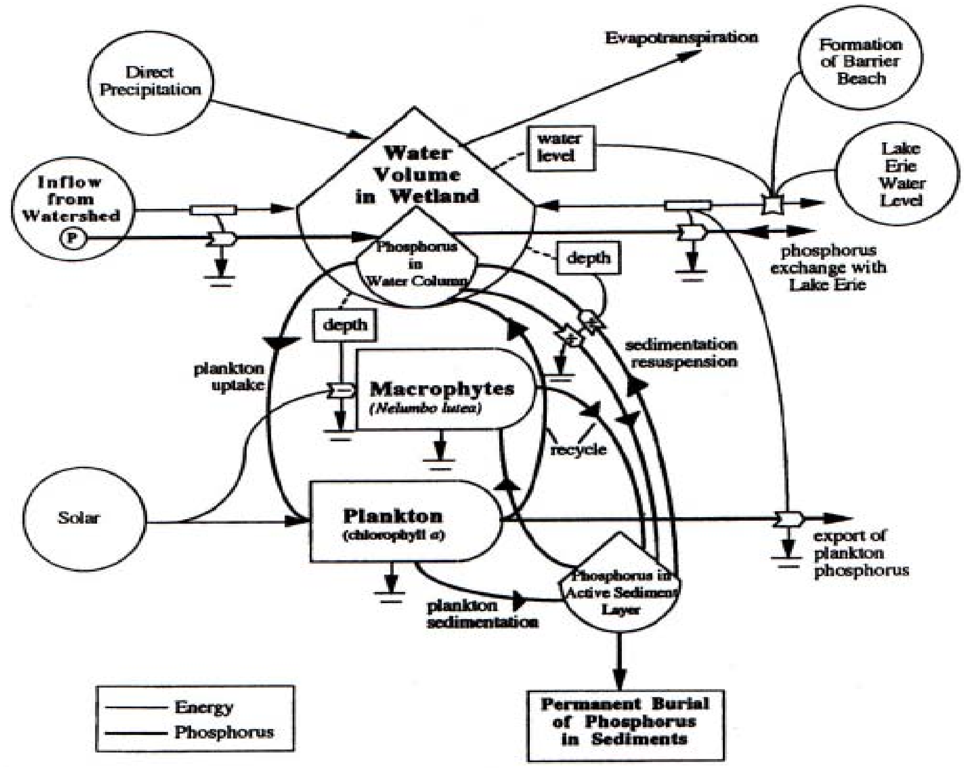


Figure 7.23. Conceptual model of ecological processes in Old Woman Creek estuary (Mitsch and Reeder 1991).

Hydrology, productivity, and phosphorus field data enabled model calibration and preliminary estimations to be made of the role of phosphorus sedimentation and phosphorus resuspension in the shallow estuary. Simulations show high levels of sedimentation in the early spring, with resuspension exceeding sedimentation through the remainder of the year. This excess of phosphorus resuspension over sedimentation in the model simulations is surprising at first, but the productivity estimates throughout the year clearly illustrate that there is insufficient phosphorus in the inflow to support the high level of productivity and the generally high phosphorus concentrations experienced in the wetland from May through November.

The model also predicts the total phosphorus sedimentation rate, including contributions from plankton and macrophytes. Sedimentation rates as high as 40 mg P $m^{-2}d^{-1}$ are simulated for the spring, while the rate for the remainder of the year, when very little allochthonous inflows are experienced, is around 10 mg P $m^{-2}d^{-1}$. The simulated rates of sedimentation and resuspension translate to a total net sedimentation of 0.8 g P m^{-2} for the 9-month study period. This contrasts to an estimated annual retention of 5-7 g P m^{-2} predicted a few years earlier using a simple empirical model (Mitsch 1989a). Because the model is based on the year 1988 which had a significant drought, the net sedimentation rate can be expected to be well below average. Thus, it is not unreasonable to suggest that the model predicted less than 20% of normal sedimentation because the calibration year was a period of extreme drought and the model was based on nine months instead of twelve. Subsequent simulations (Mitsch and Reeder 1991) show that higher inflows for the same 9-month period lead to proportionately higher net retention of phosphorus, approximately 1.3 to 3.3 g P m^{-2}, respectively, for normal and wet years.

Woodland Indians canoe the waters of Old Woman Creek estuary (artist: Jim Glover).

Chapter 8. Archaeology

Prehistoric Peoples

The historic record for northern Ohio covers nearly 350 years, from the early journals of French and English explorers and missionaries to the present day. The period of human occupation of this area before written records is about 30 times longer – the Prehistoric Period (Figure 8.1). During this period the area surrounding Old Woman Creek was inhabited by various groups of Indians. The cultural patterns of these groups are well described by Otto (1979,1980) and Shane (1992), and summarized here as a context for the archaeological investigations that have taken place in the vicinity of the Reserve.

Paleo-Indians

These peoples first inhabited southern Ohio as early as 15,000 years before the present (YBP) near the end of the Wisconsinan ice age. As the glaciers retreated and vegetation was reestablished, these nomadic hunters spread into northern Ohio following the game animals which they preyed upon. The new forests were spruce and fir and the open lands were vegetated with grasses and sedges. The game animals were also quite different from today and included woolly mammoth, mastodon, giant beaver, muskox, and caribou (Figure 8.2).

Pollen records for the Lake Erie basin show that the time between 13,000 and 9,000 YBP was characterized by major vegetational changes and, by inference, major climatic shifts (Shane 1994). As the ice retreated from the region, late-glacial warming led to the replacement of spruce forests by conifer-deciduous forests and the eventual elimination of conifer taxa on the plains surrounding the lake by 9,000 YBP (Shane 1994). During this time (13,000 to 11,000 YBP), the Paleo-Indians are thought to have entered the Lake Erie region, although there is some evidence of earlier occupation in limestone caves and rock shelters in western Pennsylvania (Adovasio et al. 1978) and on abandoned beach ridges of Lake Huron in southern Ontario (Ellis and Deller 1990, 2000). The environment was that of a boreal forest dominated by spruce and pine and human populations were most likely small and scattered (Shane 1987, 1994). Large mammalian species (Figure 8.3), such as woodland muskox (*Bootherium bombifrons*), American mastodon (*Mammut americanum*), elk-moose (*Cervaices scotti*), and giant beaver (*Castoroides ohioensis*) were present in the region at this time and are associated with boreal forest habitat (McDonald 1994). Paleo-Indians overlapped in time with these now-extinct Pleistocene mammals and there is evidence they hunted them (Fisher et al. 1994). There is little to indicate the degree of impact such exploitation may have had on these animals, but overhunting and climate change may have hastened their decline.

By 11,000 YBP winters were less extreme and summers were warmer in the Lake Erie region. Increasing diversity of vegetation and fauna would have provided multiple new environments to exploit as sources of food and shelter for human populations. The Clovis peoples entered eastern North America during the late-glacial period, just prior to 11,000 YBP, and may have been the first wave of colonizing people in the Lake Erie region (Tankersley 1994). The single most diagnostic lithic artifact of the Clovis culture is a fluted biface projectile point, referred to as the Clovis point (Agenbrood 1988). The Paleo-Indians were nomadic, probably living in small groups (40 to 60 people) that obtained most of their food from hunting with wooden spears tipped with distinctive fluted points made of flint (Figure 8.4).

One of the earliest, well-documented Paleo-Indian occupations in the Lake Erie region is the Paleo Crossing site in northeastern Ohio dated at about 11,000 YBP (Brose 1994). This Early Paleo-Indian site is located in the Cuyahoga River valley, about 70 km south of Cleveland, Ohio and is thought to have been occupied between 10,000 and 11,500 YBP based on chert artifacts, post molds, granules of charcoal, and radiocarbon dating (10,980$\pm$75 YBP). The site is characterized by lithic artifacts, particularly projectile points of the "Gainey" style (Clovis occupation), and the waste flakes from the manufacture and/or use of these tools. The 1 ha site sits on a southern break below the crest of a glacial kame located just west of a series of glacial kettle lakes. The dates and style, variety, and lithology of the tools suggest that the site represents the initial colonization of the Lake Erie basin. Likewise, the Fisher site in southern Ontario demonstrates early Paleo-Indian occupation (Storck 1997) in the region.

PREHISTORY CHRONOLOGY

18,000 BC	Asian migrants cross Bering land bridge and enter New World.	PALEO-INDIAN
9500 BC	Fluted point came into use. Few Paleo finds exceed this date.	
9000 BC	Fluted point users spread over most of North America.	
8500 BC	Transition to Archaic Period. Descendants of Paleo-Indians lived a less nomadic life.	
8000 BC	Early Archaic. Marked by first use of side notched, bifurcated, and corner notched points.	ARCHAIC
6000 BC	Middle Archaic. Many new styles of hafting designs invented. First ground stone tools such as axes and pestles developed.	
2500 BC	Late Archaic. Increased sedentism, development of elaborate mortuary complexes such as Red Ocher and Glacial Kame.	
1000 BC	Early Woodland. Widespread use of pottery. First mounds built by the Adena people in southern Ohio.	WOODLAND
1 AD	Middle Woodland. Hopewell culture appears marked by geometric earthworks, trade routes, exotic material. After a few hundred years, Hopewell system breaks down.	
400 AD	Late Woodland. Appearance of first village sites in central and southern Ohio. Use of bow and arrow begins.	
1000 AD	Fort Ancient culture in southern Ohio. Sandusky and Whittlesey traditions in northern Ohio, and Monogahela in eastern Ohio. All live in large agricultural villages and subsistence was based on maize cultivation.	LATE PREHISTORIC
1650 AD	All prehistoric people had left Ohio and Ohio was without inhabitants.	HISTORIC
1750 AD	Many Indian groups such as Shawnee, Miami, Ottawa, and Wyandot move into Ohio from other areas.	

Figure 8.1. Chronology of Ohio's Prehistoric Indians (modified from Converse 1994).

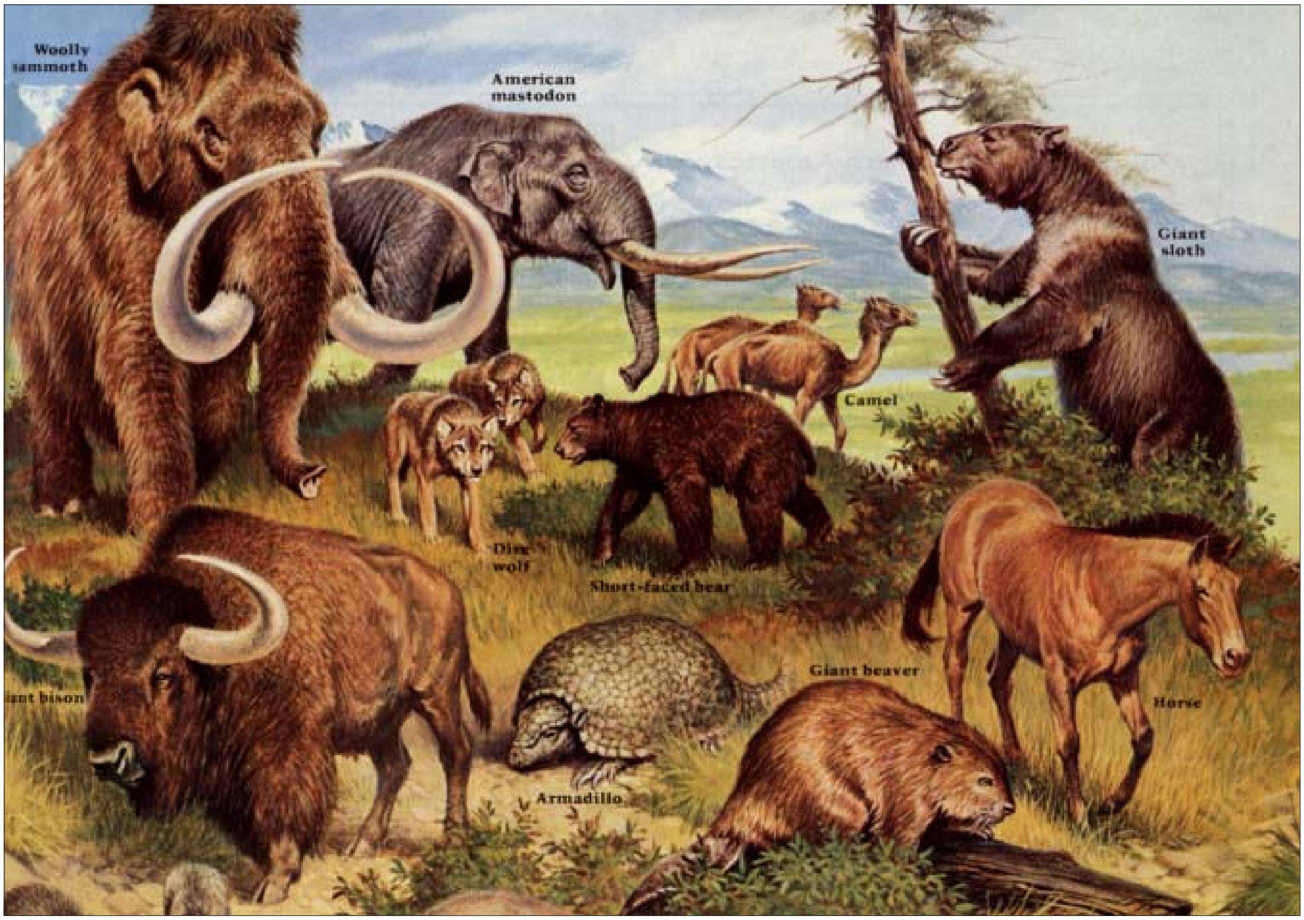


Figure 8.2. Animals of North American forests and plains 15,000 years ago (from Maxwell 1978).

Figure 8.3. American mastodon in an Ohio Pleistocene bog (after Feldmann and Hackathorn 1996).

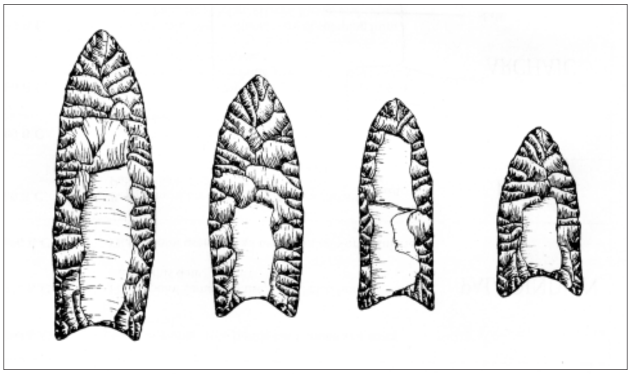


Figure 8.4. Fluted projectile points used by Paleo-Indians in Ohio (from Converse 1994).

The oldest evidence of early human occupation in the Reserve comes from excavations at the Anderson site, situated on a bluff overlooking Old Woman Creek in Erie County (Shane 1981,1992). This site (Figure 8-10), which has been occupied off and on for the past 10,000 years, may have been attractive to prehistoric people because of its well-drained sandy soil and its strategic location above the creek valley. Because Lake Erie was at least 20 m lower than present when the Paleo-Indians occupied the site, there was no estuary in the valley as there is today (Herdendorf and Bailey 1989), but the valley was probably a conduit for the movement of game and the upland terrain was rich in forest and grassland resources (Reeder and Eisner 1994).

Little remains of the camps of the Paleo-Indian hunters, other than their distinctive lanceolate-shaped spear points and perhaps the fire-stained stone cobbles scattered throughout their sites. No fireplaces, refuse pits or other facilities of the Paleo-Indians were found at the Anderson site that would permit a direct way of determining the age of the occupation. However, the spear points that were found are similar to the points found at the Squaw Rockshelter site south of Cleveland (Brose 1989) and the Paleo Crossing site in Medina County (Brose 1994). Archaeologists at the Cleveland Museum of Natural History have obtained radiocarbon dates ranging from 9,200 to 11,000 YBP for wood charcoal that was associated with the fluted points. A similar age is suspected for the Paleo-Indian occupation at the Anderson site.

From 11,000 to 10,000 YBP the climatic conditions in the region became more complex, with short-term temperature and moisture reversals in contrast to the gradual warming trends of earlier millennia. Increased mobility in human populations seems likely during this period because the landscape was no longer predictable from generation to generation. Prolonged drought conditions would have placed unprecedented stresses on human and animal populations (Shane 1994).

Stothers and Abel (2001) point out that an enormous amount of archaeological information has “vanished beneath the waves” of Lake Erie. Research on the glacial geography and environment of the Lake Erie basin has presented the opportunity to correlate Wisconsinan ice masses, glacial lakes, and paleo-environments with various Paleo-Indian and Early Archaic cultural complexes. Beginning about 14,250 YBP, glacial retreat allowed the Eastern Basin of Lake Erie to drain along the edge of the Appalachian Plateau to the Mohawk River. As a result, Early Lake Erie was established about 12,400 YBP at a level as much as 30 m below the present lake level (Bolsenga and Herdendorf 1993). Thus, by 11,000 YBP when the first humans arrived on the scene, they likely settled areas of the lake basin that have long since disappeared under the gradually rising lake (Stothers and Abel 2001). The detailed bathymetry revealed by recent investigations (Holcombe et al. 2001a,b) may yield potential sites of prehistory occupation. The complex terrain features of the former peninsulas and islands which now comprise the submerged Pelee-Lorain Ridge, some 25 km northeast of the Reserve, may hold the most promise for the discovery of such sites.

Later in the Paleo-Indian period, another group of hunters called the Plano Complex moved into northern Ohio from the west (about 9,500 YBP). Artifacts from this culture have been found associated with the abandoned beach ridges formed around the glacial lakes that once occupied the Lake Erie basin at levels up to 64 meters above the present level of Lake Erie (Otto 1980, Herdendorf 1989).

ARCHAIC INDIANS

The warming trend was re-established during the period from 10,000 to 9,000 YBP as climatic parameters approached modern values and gradients. Spruce, hemlock, pine, and larch either disappeared or were restricted to sheltered ravines; oak, hickory, walnut, and maple became the dominant trees. Later, 7,000 to 6,000 YBP, beech became important (Shane 1994). Human populations would have been affected by the loss of conifer forest, but the more diverse and plentiful fauna of the deciduous forest that replaced them and the milder winters would have also increased forage opportunities.

These new opportunities coincided with occupation of the region by people of the Archaic culture (Otto 1980) whose economy was based on hunting, fishing, and gathering. With the expansion of the deciduous forest into northern Ohio, Archaic Indian peoples adapted to the changing environment by developing new food sources and modifying technologies to utilize the resources of the newly established woodlands. In addition to hunting game, such as deer, they gathered plant foods, especially from nut-bearing trees (e.g. oak, hickory, and walnut).

The Ringer dugout canoe (3,600 YPB), found in the remnant of a glacial lake in Ashland County, Ohio at the head of the Vermilion River which flows into Lake Erie, suggests that Archaic people were engaged in water-borne trade in the region (Brose and Greber 1982). This canoe is believed to have had a cargo capacity of about 530 kilograms (kg) plus two crew members. Rather than the long-distance canoes of the later Woodland people (used to transport such commodities as copper, mica, flint, pottery, fresh conch shells, and salt), the Archaic canoe seemed best suited for local travel, carrying passengers and subsistence cargoes (Figure 8.5).

Most sites found in northern Ohio seem to have been small hunting camps. Typically these camps were located on a vantage point above a stream valley to maximize hunting efforts by utilizing bluff tops as observation areas to locate and pursue deer moving through the valley (Abel 1994). Although there is abundant evidence of Archaic period occupations in northern Ohio, only a few Archaic artifacts were found in the areas excavated along Old Woman Creek. However, the Weilnau site on the Huron River in Erie County, Ohio has been interpreted as a seasonal hunting

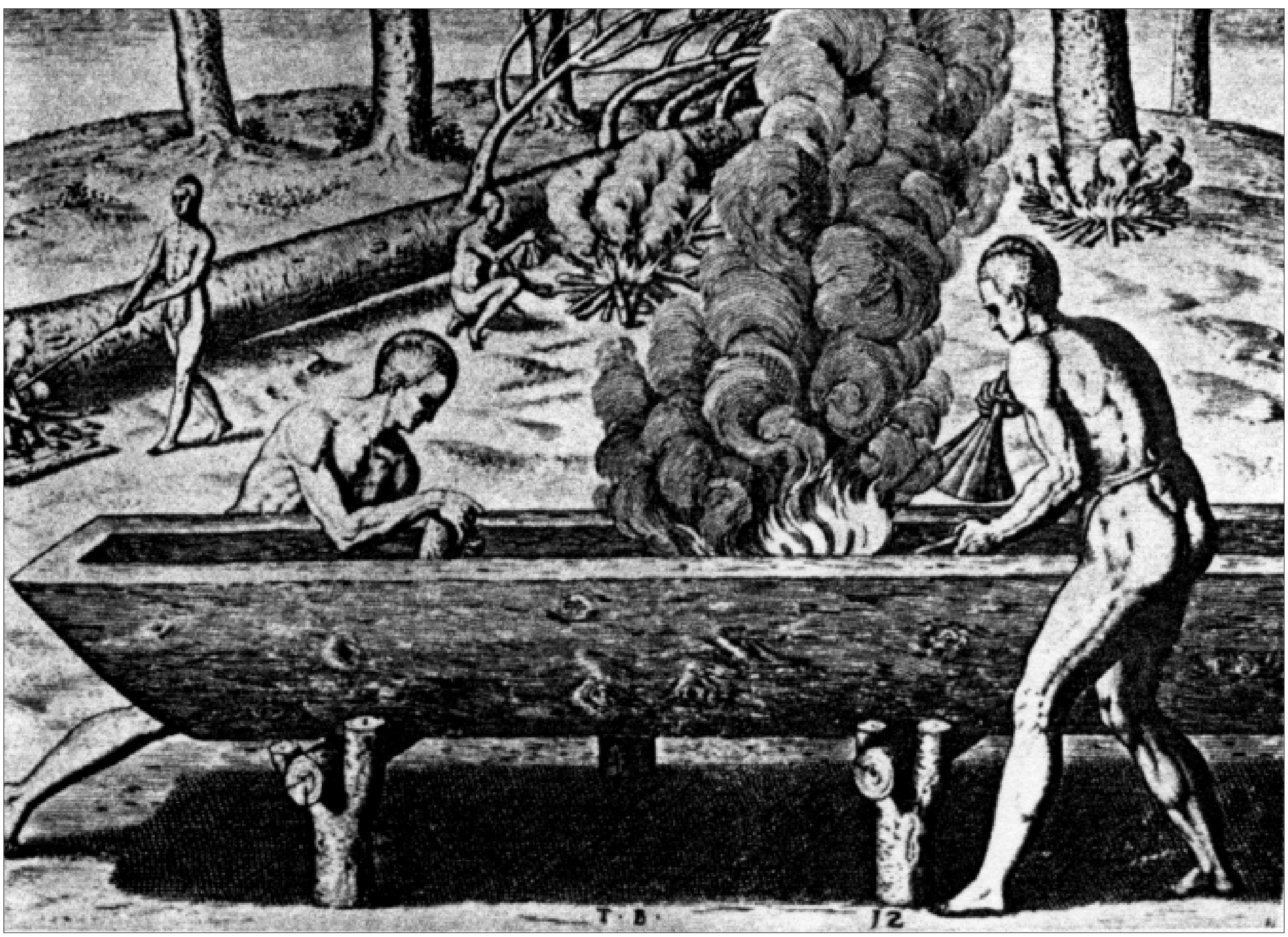


Figure 8.5. Engraving of American Indians making a dugout canoe (from Harriot 1590).

camp for these people (Abel 1994). Archaic peoples established hunting and fishing camps in various parts of their territories during different seasons of the year according to the availability of food resources.

In addition to chipping spear points and knives from flint, Archaic Indians developed a technique for making axes and various types of food processing tools. They tended to use hard rocks for these purposes, such as granite erratics which are abundant in the glacial deposits of the watershed and in the hollows between the ancient beach ridges (Campbell 1955, Herdendorf 1963). Lake Erie bifurcated-base and Stanley stemmed-base points found at the Weilnau site (Abel 1994) indicated an age of 8,300 to 7,800 YBP, which corresponds to the Early Archaic cultural period in northern Ohio; whereas Brewerton side-notched and Genesee projectile points from the Anderson site indicate Late Archaic peoples (5,000 to 3,500 YBP).

The Weilnau site, located on a high bluff overlooking the Huron River valley in Milan Township, Erie County, Ohio contained a habitation structure and projectile points associated with the Early Archaic period (Abel and Haas 1991, Abel 1994). The habitation structure consisted of a shallow, circular depression (3.2 m in diameter) surrounded by post molds. A cluster of fire-cracked rocks near its center was interpreted as a hearth. Abel (1994) interpreted the Weilnau site as a hunting camp. The site offers a clear view of the broad floodplain and meanders of the Huron River, some 20 m below. The valley constricts immediately downstream of the site forming a bottleneck for game moving in that direction. Abel postulated that Early Archaic hunters used the bluff tops near the site as observation points to locate and pursue deer and other game moving through the valley. The habitation structure and the hearth suggests cold-weather occupation (autumn and winter), when deer are most mobile and best hunted. The Huron River valley was probably utilized heavily by deer during these seasons, especially since the river rarely freezes below the site under current climatic conditions and most certainly was ice-free during the mild Climatic Optimum (8,000 to 6,000 YBP).

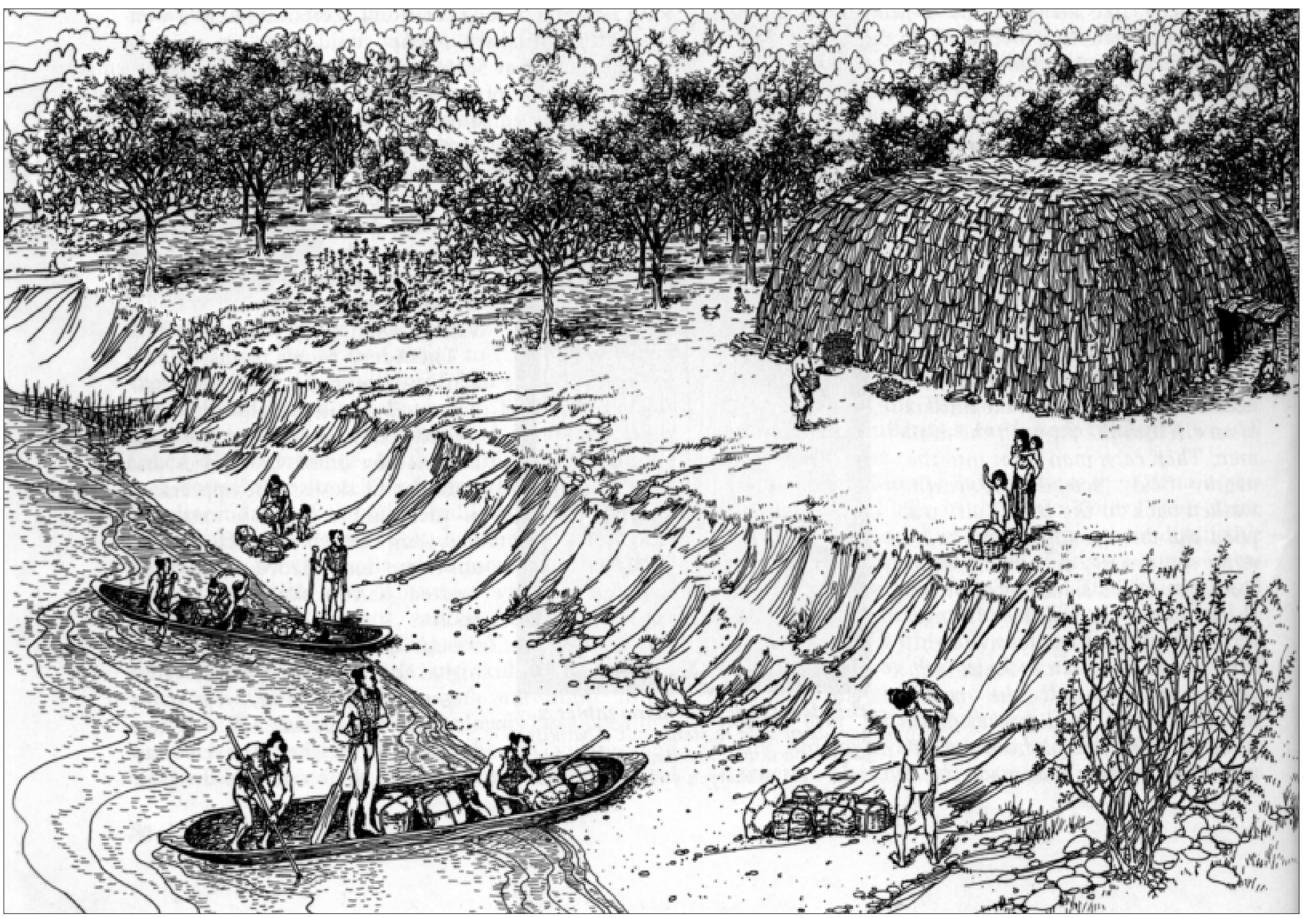


Figure 8.6. Depiction of a Woodland Indian village in northcentral Ohio (from Maxwell 1978).

Figure 8.7. Seasonal hunting camp typical of Archaic and Woodland Indians (from Maxwell 1978).

WOODLAND INDIANS

About 3,000 YBP the way of life of Indian people in much of eastern North America began to undergo a fundamental change, largely in response to the domestication and cultivation of plants. With crops to supplement food traditionally obtained by hunting and gathering, they were eventually able to establish more or less permanent villages (Figure 8.6). Fired, clay pottery also appeared at this time, permitting resources to be stored, which also favored more permanent settlements. Thus, these peoples began to follow a yearly round of activities, in part controlled by the need to come together in summer to plant, cultivate, and harvest crops. Archaeologists call this last 3,000 years of eastern North American prehistory the Woodland Period (Shane 1992).

One of the most extensively documented and perhaps the single most important aboriginal wild plant food source associated with the embayments of Lake Erie was wild rice (*Zizania aquatic* and *Z. palustris*). Wild rice constituted a food staple for most Algonquian- and Siouan-speaking tribal groups living in the Great Lakes region (Keenlyside 1978). The occurrence of "once abundant stands" of wild rice at Point Pelee and Long Point, Ontario may have been one of the primary attractions for late prehistory aboriginal peoples.

At first, Woodland farmers cultivated only indigenous Midwestern plants for their seeds, such as the marsh elder (*Iva*), lamb's quarter (*Chenopodium*), gourd (*Largenaria*), and perhaps sunflower (*Helianthus*); these crops were later replaced by cultivated corn, beans, and squash introduced from Mexico (Shane 1992). Perhaps for the next 2,000 years, cultivated plant foods supplemented a subsistence economy based on hunting, gathering, and fishing. By about 900 A.D., Indian farmers became reliant on corn, beans, squash, and sunflower for a significant portion of their food (Prufer and Shane 1976). At about the same time bows and arrows came into common use for hunting (Figure 8.7).

The major village at the Anderson site was occupied during the 15th century, in the Late Prehistoric Period. Although the villagers grew corn, as evidenced by the carbonized kernels recovered from village refuse pits, the large amounts of animal remains and nut shells indicate that farming may have been less important to the village economy than hunting, fishing, or gathering. Evidence for angling with hook and line at the Anderson site includes polished bone fishhooks. Fish from Lake Erie and its estuaries were probably also taken with nets, traps, or spears. Although little archaeological evidence remains of these devices at the Anderson site, such devices were found at the Harbour site (Late Prehistoric – 900 YBP) on Pipe Creek where it flows into Sandusky Bay, Erie County, Ohio. While only the remains of catfishes, northern pike, and freshwater drum were recognized at the Anderson site, 27 fish species were identified at the Harbour site by Cavender and Bowen (1994), demonstrating an extensive use of the Lake Erie fishery; identified species included:

Ambloplites rupestris (rock bass)
Amia calva (bowfin)
Aplodinotus grunniens (freshwater drum)
Coregonus artedii (cisco)
Erimyzon sucetta (lake chubsucker)
Esox americanus (grass pickerel)
Esox lucius (northern pike)
Esox masquinongy (muskellunge)
Ameiurus melas (black bullhead)
Ameiurus natalis (yellow bullhead)
Ameiurus nebulosus (brown bullhead)
Ictalurus punctatus (channel catfish)
Lepisosteus osseus (longnose gar)
Lepomis gibbosus (pumpkinseed sunfish)
Lepomis macrochirus (bluegill sunfish)
Micropterus dolomieui (smallmouth bass)
Micropterus salmoides (largemouth bass)
Minytrema melanops (spotted sucker)
Morone chrysops (white bass)
Moxostoma anisurum (silver redhorse)
Moxostoma cariinatum (river redhorse)
Moxostoma erythrurum (golden redhorse)
Moxostoma macrolepidotum (shorthead redhorse)
Notemigonus crysoleucas (golden shiner)
Perca flavescens (yellow perch)
Pomoxis annularis (white crappie)
Sander vitreus vitreus (walleye)

All of these species, with the exception of the river redhorse and cisco, have been reported in the vicinity of Old Woman Creek estuary during the past 50 years (Herdendorf et al. 2001d). The Harbour site fish assemblage represents the shallow, nearshore waters habitat of Sandusky Bay and the deeper waters of Lake Erie about 900 YBP. Many small and medium sized fishes were present along with some very large individuals. The wide size variation and high diversity indicates capture by trap or seine, a hypothesis that is supported by the recovery of netsinkers at the site. Collection grounds with relatively firm, unobstructed bottom conditions were probably selected close to the village. The dominance of adult pumpkinseed sunfish suggests these were taken during the early summer spawning season when adults were easily captured in shallow water by seining. Some open water species were present, but most share an affinity with shallow, vegetated margins of the bay. Other vertebrates identified from refuse pits and middens at the Harbour site, such as muskrats, ducks, turtles, and frogs, agree with the fishes in habitat preference (Cavender and Bowen 1994).

Studies of animal bones from prehistoric Indian habitations in northern Ohio show that white-tailed deer was the single most important game animal for the Woodland people (Shane 1992). In addition to meat, deer provided hide for clothing, bone and antler for tools and utensils, sinew for thread and binding material, and brain for tanning. Elk, raccoon, rabbits, bear, and wild turkey were also hunted in the upland forest surrounding the estuary. Beaver, muskrats, and waterfowl were taken from the wetlands.

Wild plants from the wetlands along the shore embayments of Lake Erie and from the upland forests appear to have provided at least half of the foods eaten by Woodland people. Nuts, numerous kinds of seeds of herbaceous plants, and greens were collected from the forest, as were many medicinal plants. Hickory nuts, in particular, were crushed and boiled in water to release their oil, which was collected and used for cooking. Wetland plants provided raw material for making mats, baskets, bags, house coverings, and a great many wood utensils. Cattails, bulrushes, the inner bark of basswood, and elm were important materials.

Fired clay pottery vessels and smoking pipe bowls were fashioned from clay probably collected from a source along Lake Erie tributaries (Shane 1992). Pots were unpainted and were decorated along the rim with bands of simple rectangular tool impressions. Oval post-mold patterns, floor depressions, and hearth structures at the Anderson site indicate that Late Prehistoric houses were similar to the 17th to 19th century dome-shaped lodges or "wigwams" built by Ottawa and Sauk Indians of the western Great Lakes region. These houses probably consisted of oval pole frames, covered with various available kinds of tree bark and bulrush or cattail mats.

Late Prehistoric and Contact Indians

The last prehistoric culture to inhabit northwestern Ohio was known as the Sandusky Tradition which presumably arrived from the south about 1,000 A.D. Contemporary groups of Indians in northeastern Ohio and northwestern Pennsylvania were known as the Whittlesey Tradition and in southern Ohio as the Fort Ancient Culture. Members of the northern cultures may have been the ancestors of the Erie Indians who were reportedly destroyed as a group in northeastern Ohio by the marauding Iroquois from western New York in 1654 (Otto 1980). These people inhabited small villages built on promontories on high banks overlooking streams that emptied into Lake Erie. Communities were fortified with palisades and exterior ditches (Figure 8.8).

Late Prehistoric Indians used the bow and arrow for hunting. The proximity of the lake and rivers to villages enabled these people to fish extensively, both with hooks and with nets. Their nets were weighted with rounded pieces of stone, particularly slate which was roughly notched on opposite edges for attachment to the nets (Otto 1980). They also cultivated corn and collected wild plant food and mussels.

Around 500 YBP the northeastern shore of Lake Erie was inhabited by ancestral Neutrals, followed by the Neutrals and Tobacco Indians about 400 YBP (Addison 1994). These peoples were also subdued by the Iroquois Indians, as were the people of the Huron Nation who resided to the north around Georgian Bay. Archaeological investigations indicate that both the Neutrals and the Iroquois occupied a relatively small area between Lakes Erie and Ontario and used the hinterlands of the north shore as hunting grounds (Burns 1985, Ellis and Ferris 1990). These groups represent the region's Contact Indians. However, there were very few Indians living along the north shore of Lake Erie when the first Europeans began to move through the area in the late 17th century (Noble 1978). Likewise, the south shore had very few aboriginal inhabitants at this time (Figure 8.9).

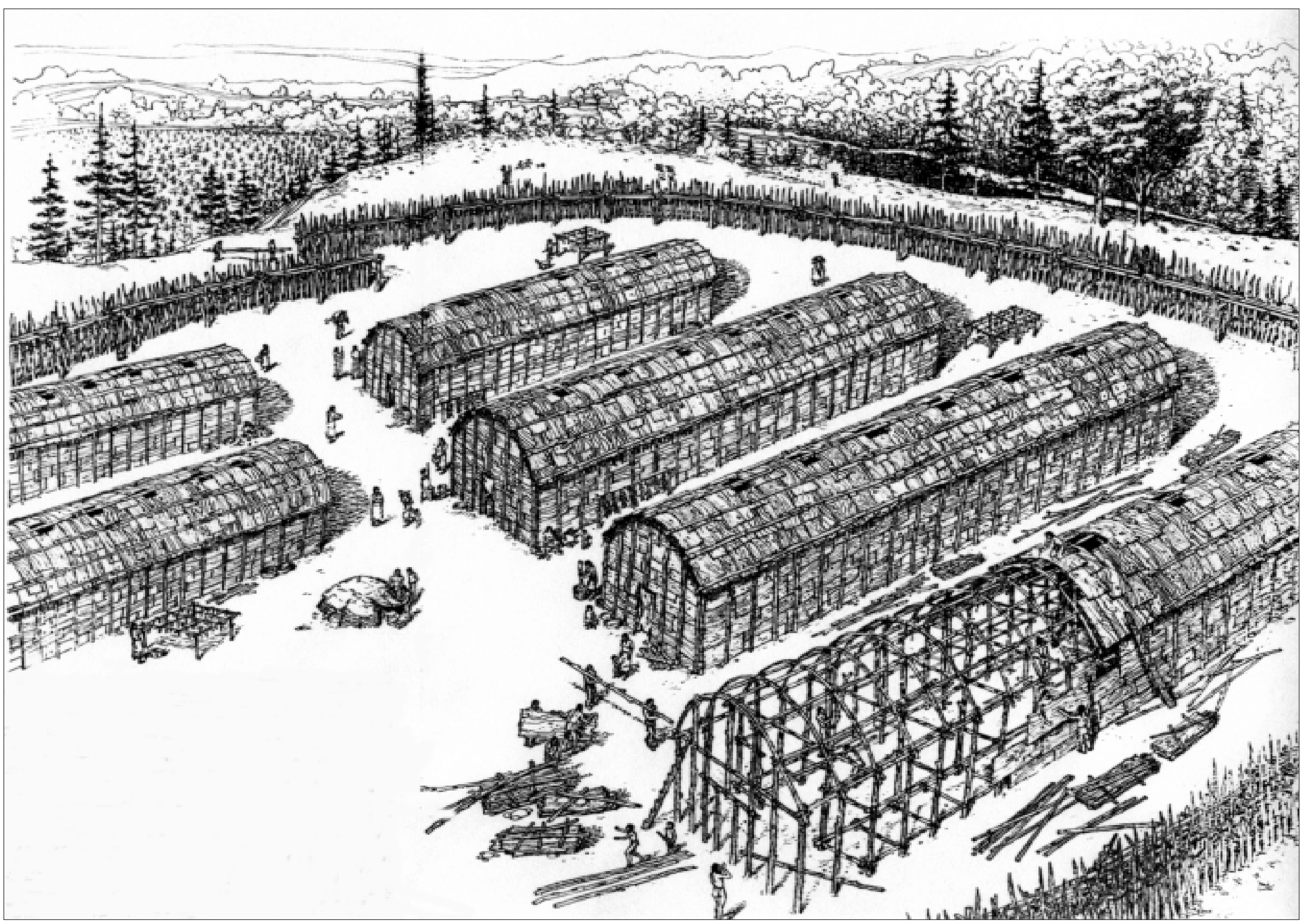


Figure 8.8. Early 17th century village of Erie and Seneca Indians (from Maxwell 1978).

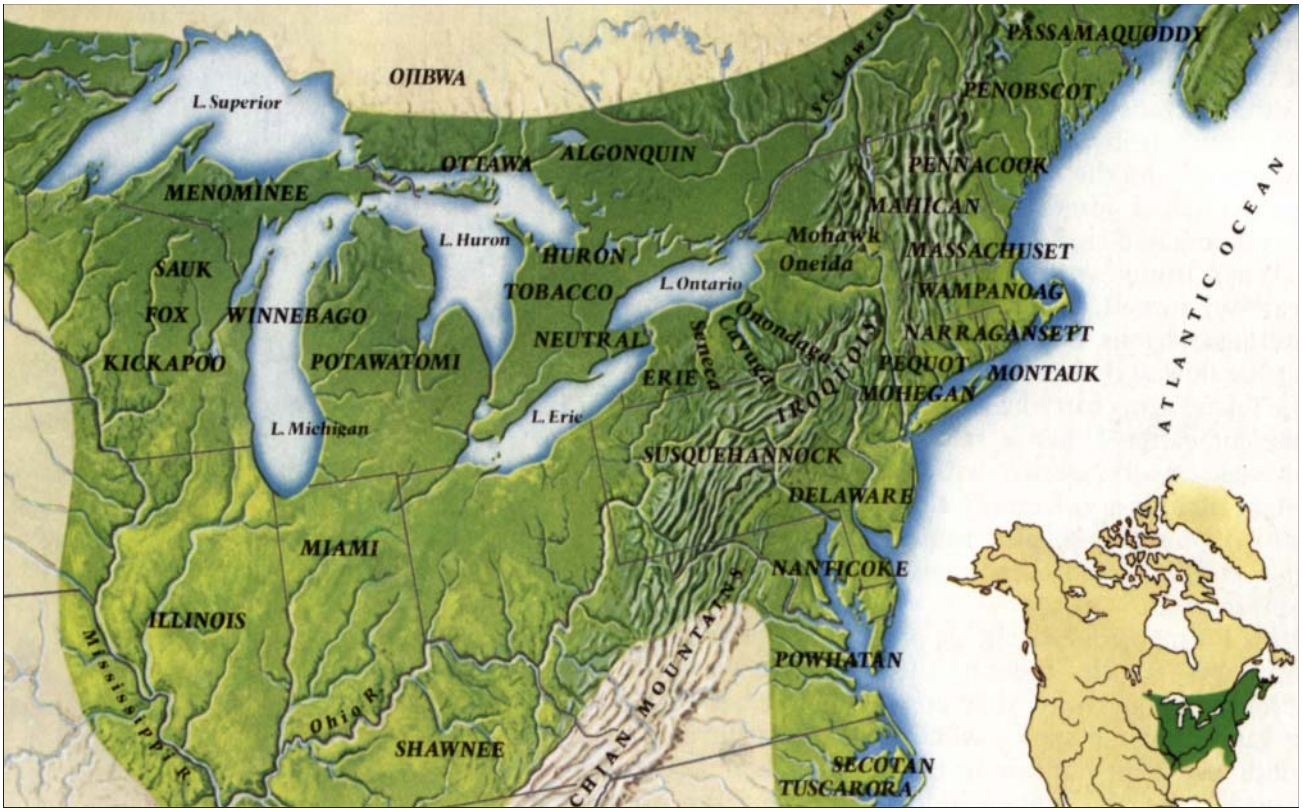


Figure 8.9. Tribal groups in the Great Lakes region when Europeans arrived (from Maxwell 1978).

ARCHAEOLOGICAL INVESTIGATIONS

Two archaeological sites (Anderson and Jenkins) overlooking Old Woman Creek estuary and a third site (Enderle) 4 km to the west on the Huron River estuary were excavated in 1976 and 1977 as part of a highway mitigation project before the construction of Ohio Route 2 which traverses the Reserve near the southern boundary (Figure 8.10). The results of these investigations were reported by Seeman and Bush (1979) and Shane (1981,1992). These sites document occupation by Paleo-Indian, Archaic, and Woodland peoples. A fourth site (Weilnau), located 10 km farther upstream on the Huron River, was excavated in 1990 (Abel and Haas 1991, Abel 1994). This site provides additional information on the Early Archaic culture in the vicinity of the Reserve. All four sites occupy high ground overlooking resource-rich estuaries or stream valleys.

JENKINS SITE

This is a small multi-component site situated on a promontory forming the eastern bluff of the Old Woman Creek valley, at an elevation of 185 m (608 feet) above mean sea level (MSL) The soils at the site (Del Rey loam) formed in glacial lake sediments (Redmond, et al. 1971). Four cultural features were found beneath the plowzone. Each was a circular, reddish discoloration of the subsoil, containing minute charcoal flecks. Shane (1981) interpreted these as the bases or burned soil "ghosts" of hearths that were originally located higher in the soil. The actual hearths were probably destroyed by plowing when modern agricultural practices were introduced at the site.

No artifacts were associated with the hearth features. Surface surveys indicated that the vast majority of the Jenkins site lies in the Reserve north of the Ohio Route 2. The greatest concentration of surface artifacts were found on sandy knolls approximately 50 m north of the highway right-of-way. These artifacts and a few items from the plowzone near the hearths confirm the presence of both Archaic and Late Woodland components at the site. Based on the finding that a significant portion of the site was located north of the right-of-way, Shane (1981) concluded that construction of the highway would not severely impact the site.

Figure 8.10. Archaeological sites in the vicinity of Old Woman Creek State Nature Preserve and National Estuarine Research Reserve (base map from Ohio Atlas & Gazetteer, Fifth Edition, DeLorme, Yarmouth, Maine, 1999).

ANDERSON SITE

This is also a multi-component site that is located on a promontory forming part of the western bluff of Old Woman Creek valley, at elevation of 185 to 187 m (608 to 614 feet) above MLS. The soil at the site (Metea loamy fine sand) formed in glacial Lake Lundy sediment (deposited ca. 12,400 YBP). This late Pleistocene sand deposit was about 1.5 m thick at the crest of the promontory and thinned toward the edges where it intersected an underlying silt and clay deposit (Sisson silt loam). Excavations revealed that most of the cultural materials were in the upper 60 cm of the sand deposit.

A total of 163 cultural features were identified and excavated at the site, including:

Refuse/Storage Pits	104
Hearths & Hearth Bases	30
Middens & Sheet Middens	14
House Floor & House Depressions	4
Post Mold	1
Defensive (?) Enclosure	1
Rock-Filled Pit	1
Historic/Modern Refuse Deposits	3
Indeterminate	5

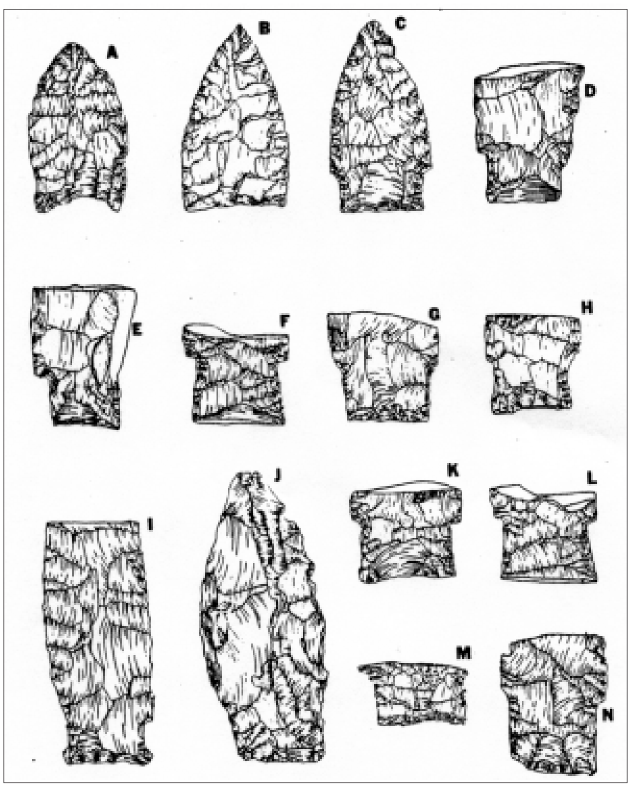


Figure 8.11. Late Paleo-Indian projectile points from the Anderson site (Shane 1981). A, B—Hi-Lo type points; C–N—Scottsbluff type points.

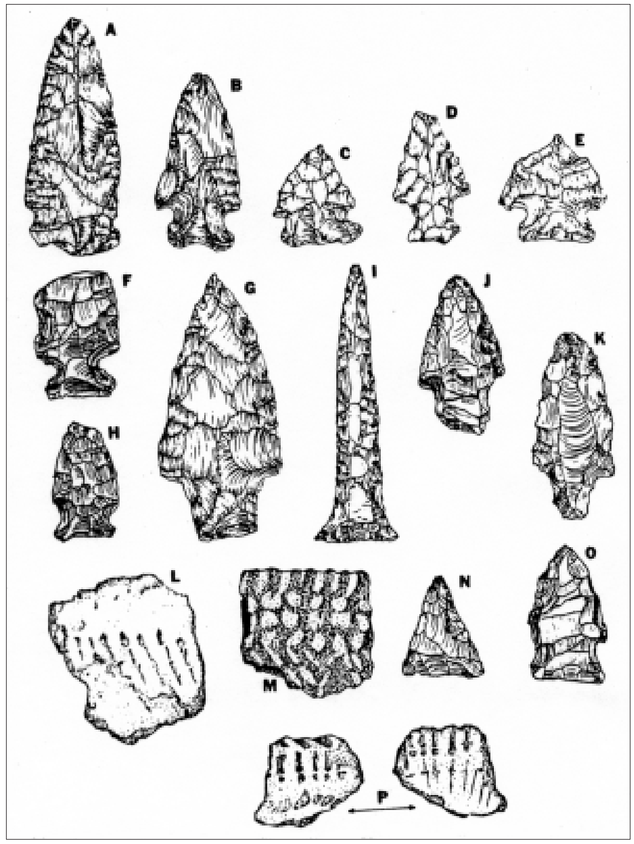


Figure 8.12. Archaic and Early Woodland artifacts from the Anderson site (Shane 1981). Archaic period: A–F, H—Brewerton side-notched projectile points; G—Genesee point; I—expanded base drill. Early Woodland period; J–K—stemmed projectile points; L, M, P—thicked-walled grit-tempered cordmarked pottery; N, O—leaf-shaped chert bifaces.

The following occupational history of the Anderson Site is based on the work of Shane (1981,1992). Initial occupation of the site was by Late Paleo-Indian hunters (10,500-9,000 YBP) who used stemmed and unstemmed lanceolate projectiles (Hi-Lo and Scottsbluff types) to take down their prey (Figure 8.11). Other stone tools, such as spurred end scrapers, blades, and end scrapers on blades, which are often associated with Late Paleo-Indian sites, were not recovered. Following this occupation there appears to be a cultural hiatus until the site was utilized by Late Archaic hunter/gatherers (5,000-3,500 YBP). Artifacts found at the site that are associated with these people include: Brewerton side-notched projectile points, Genesee points, expanded-base drills, and polished slate atlatl weights (Figure 8.12). No specific features were associated with either the Late Paleo-Indian or Archaic artifacts, leading to the interpretation that the occupations were of a transitory nature or were centered elsewhere in the area.

Evidence for Early Woodland habitation (2,800-1,900 YBP) at the site is more positive – a hearth and 4 refuse pits. These yielded stemmed projectile points, thick-walled grit-tempered cord-marked pottery, and leaf-shaped chert bifaces (Figure 8.12). The next occupation was the Late Woodland culture (800-650 YBP) and is represented by a small component at the site. A bell-shaped refuse pit contained pottery similar to the Vase tool-impressed type of the Late Woodland Western Basin Tradition of northwestern Ohio and southeastern Michigan. Wood charcoal from the pit yielded a radiocarbon date of 1280±65 A.D. (DIC-790). Animal remains in the pit indicated deer, muskrat, birds, and fish were food sources.

By far the most important component at the site was a 15th century Sandusky Tradition village. The most striking feature was a roughly circular enclosure (~64 m in diameter) that was bounded by a trench, 9 m wide and 1 m deep. This feature enclosed an area of approximately 3,250 m^2 and contained three possible house structures within its confines. The trench appears to have served as a defensive structure for the village. A radiocarbon date of 1460±125 A.D. (DIC-788) was obtained for material in the trench, whereas a date of 1690±100 A.D. (DIC-785) was determined for material in an interior refuse pit. Cultural debris was scattered throughout the enclosure trench in discontinuous deposits. Grit-tempered pottery included 100 smooth and 42 cord-marked body sherds, 11 Mixter tool-impressed rim pieces from 10 vessels, 8 Parker Festooned rim pieces from 6 vessels, 7 Mixter cord-marked rim pieces from 4 vessels, 4 Reeve opposed rim pieces from 2 vessels, and numerous basal sherds (Figures 8.13 and 8.14). The Mixter tool-impressed and Parker Festooned types were represented by totally reconstructable vessels.

A variety of projectile points were also found, including Madison triangular points (Figure 8.15) which are diagnostic of Late Woodland and Mississippian cultures (Justice 1987). The enclosure contained at least 3 depressions and floors thought to be the remains of houses and numerous refuse deposits. The refuse pits, hearths, and middens contained straight drills, "hump-backed" scrapers, ground slate celts, manos, metates, bi-polar cores, clay pipes, flaked slate choppers, sandstone beads, netsinkers, and chert flakes, cores, and debitage (Figure 8.15).

Both plant and animal remains were abundant in the refuse pits and middens. Floral remains included maize, hickory nut, butternut, acorns, and walnut, while faunal remains were deer, muskrat, rabbit, small rodents, birds, fish (especially bullheads, pike, and freshwater drum), and mollusks. Maize was the most common food source found in the pits.

Excavations revealed that a contemporary settlement was located immediately to the east of the defended village. A group of features were arrayed in an irregular circle that yielded pottery very similar to that from the village. A conical refuse pit yielded a radiocarbon date of 1650±75 A.D. (DIC-787). The refuse pits in the settlement differed from those in the village in that although they contained abundant plant residual, animal remains were largely absent. Additionally, over 100 complete or fragmentary grinding stones were recovered in the vicinity of the settlement, suggesting that the features to the east of the village represent a functionally different settlement type.

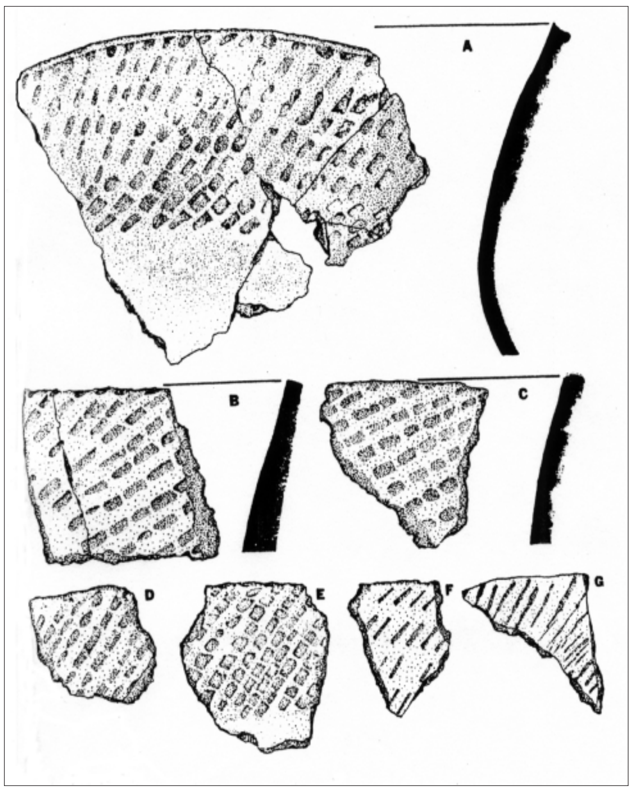


Figure 8.13. Late Prehistoric ceramic types from the Anderson site (Shane 1981). A–G—Mixter tool-impressed sherds.

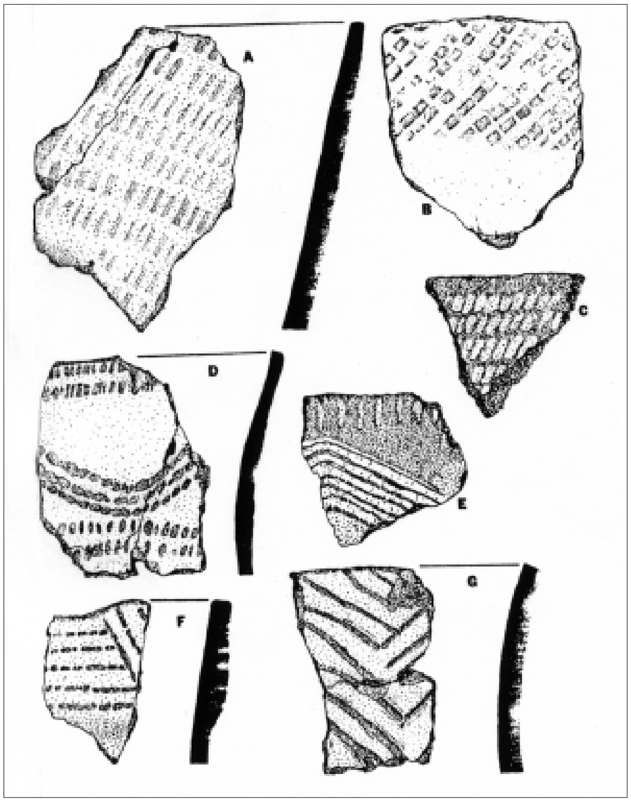


Figure 8.14. Late Woodland ceramic type from the Anderson site (Shane 1981) A–C, F—Mixter tool-impressed sherds; D, E, G—Parker Festooned sherds.

ENDERLE SITE

Located on a broad meander of the lower Huron River about 2 km south of Lake Erie (3 km west of the Old Woman Creek watershed), this small multi-component site contained historic Indian burials and Late Woodland artifacts. The site is centered on sandy knolls that undulate from 183 to 186 m (600 to 610 feet) above MSL. The knolls represent stabilized dunes that were formed during the low stage of Lake Erie following the recession of glacial Lake Lundy (~12,400 YBP). The site is about 6 m above the water level of the Huron River Estuary.

Three burials occupied the apex of one of the knolls, lying parallel about 1 m apart, and oriented in a north-south direction. Laboratory analyses indicated that the burials were all young adult Indians (2 females and 1 male) which date from AD 1760-1780 based on associated cultural materials, such as hand-wrought iron nails, numerous "trade beads" made of white and black glass, metal vanity objects including silver and brass rings, and pieces of French cotton fabric with floret designs. Wood preserved by the rust of the nails may represent the remains of a rectangular coffin (Seeman and Bush 1979). A loosely woven mat of noded reed-like material (probably *Equisetum arvense*, common horsetail) appears to have been used to line the coffins. This appears to represent a transition in burial practices with the reed mat being a traditional Indian element and the coffin being a European element. Cultural contact situations are often characterized by "differential borrowing" such as this.

Thousands of white glass "seed beads" appeared to have been sewn on clothing of the females in a specific zigzag design. A choker-style, beaded necklace (composed of 230 black, glass tubular beads) was found at the neck of one of the females. Near the cranium, at the same burial, a massive concentration of 700 white "seed beads" was found with a number of greasy, vermilion lumps near the center. In the 18th century the Delaware Indians had a mortuary practice of breaking a hole in a sealed coffin to place a bag of vermilion near the head; the hole also served to released the deceased's sprit (Newcomb 1956). The glass beads

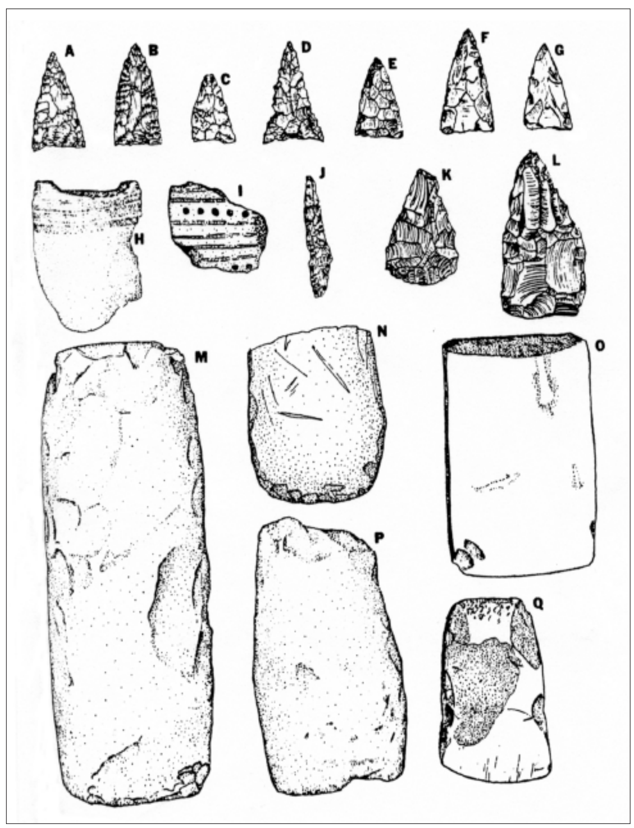


Figure 8.15. Late Woodland artifacts from the Anderson site (Shane 1981). A–G—Madison triangular projectile points; H, I—pipe fragments; J—straight drill; K, L—"hump-backed" scraper; M–Q—ground slate celts.

found near the cranium may have been sewn on the outside of such a pouch. The skeletons showed no obvious signs of trauma or debilitating pathology; thus the causes of the deaths could not be determined from the available evidence.

If the temporal placement of the Enderle burials in the late 18th century is correct, then it is likely the 3 individuals were Wyandot or Delaware. The Wyandot (formerly Huron Indians from southern Ontario) moved into northwestern Ohio during the mid-1600s and were concentrated along Sandusky Bay by the late 18th century. However, the Wyandot retained the Huronian ossuary type of burial practice until considerably after the period of the Enderle burials (McKenzie and Prufer 1967). The other possibility is that the Enderle burials are Delaware. During the period 1789 to 1804 two Moravian Delaware settlements (New Salem and Petquoting) were established on the Huron River within 5 km upstream of the Enderle site. The diary of one of the founders, Gotfried Oppelt, records the presence of a large "pagan" Delaware village downstream of Petquoting (White 1976). The possibility that there was a traditional Delaware village near the site, and that it was occupied only slightly later than the Enderle site, suggests than the burials could have been Delaware.

In addition to the 3 burials, several nearby refuse pit features produced artifacts indicative of Woodland affiliation, but none contained cultural material that was contemporary with the burial features. The pits contained pottery pieces, mostly grit-tempered, cord-marked, vessel-body sherds. On another knoll, immediately east of the burials, excavations in the upper soil horizons yielded artifacts and debitage representative of several Archaic and Woodland components (Figure 8.16). The bulk of these materials appear to be related to the Late Woodland workshop activities. Once the excavation of the burial features and the shallow Woodland features were completed, the field archaeologists concluded that it was unlikely that highway construction for Ohio Route 2 would adversely impact any remaining cultural resources in the locale (Shane 1981).

Figure 8.16. Reconstructed example of a Late Woodland dwelling (Jim Herbstritt).

Weilnau Site

This site, located on a high bluff overlooking the Huron River valley in Milan Township, Erie County (approximately 6 km west of Old Woman Creek watershed), contained a habitation structure and projectile point associated with the Early Archaic period (Abel and Haas 1991, Abel 1994). The habitation structure consisted of a shallow, circular depression (3.2 m in diameter) surrounded by post molds. A cluster of fire-cracked rocks near its center were interpreted as a hearth. Several Lake Erie bifurcated-base points and a Stanley stemmed-base point found within the structure indicated an age of ca. 8,300 to 7,800 YBP, the period of the Early Archaic culture in northern Ohio (Justice 1987).

Abel (1994) interpreted the Weilnau site as a hunting camp. The site offers a clear view of the broad floodplain and meanders of the Huron River, some 20 m below. The valley constricts immediately downstream of the site forming a bottleneck for game moving in that direction. Abel postulated that Early Archaic hunters used the bluff tops near the site as observation points to locate and pursue deer and other game moving through the valley. The habitation structure and the hearth suggests cold-weather occupation of the camp (autumn and winter), when deer are most mobile and best hunted. The Huron River valley was probably utilized heavily by deer during these seasons, especially since the river rarely freezes below the site under current conditions and most certainly was ice-free during the mild temperatures of the Climatic Optimum (8,000 to 6,000 YBP).

Abandoned single-row cornstalk binder on the Edward Walper Trail, Old Woman Creek NERR (Charles E. Herdendorf).

Chapter 9. Land Use

Pre-History Land Use

Archaeologists believe the ancestors of American Indians spread into North America from Asia soon after 20,000 years ago. These First Americans moved south and east into what is now northern Ohio shortly after the ice of the last great continental glaciers retreated northward. By about 11,000 years ago people called Paleo-Indians roamed the southern Great Lakes region, most likely hunting elephant-like herbivores, the American mastodon (*Mammut americanum*) and the mammoths (*Mammuthus primigenius* and *M. columbi*), the giant beaver (*Castoroides ohioensis*) a black bear-sized rodent, the ox-sized ground sloth (*Megalonyx jeffersonii*), the caribou (*Rangifer tarandus*), the tundra muskox (*Ovibos moschatus*), the elk-moose (*Cervalces scotti*) and several other Ice Age animals (Feldmann and Hackathorn 1996).

Lake Erie was already several thousand years old by this time, and Indian people began to take advantage of the rich biological diversity among the plant and animal communities of the lakeshore and tributary streams. The lower Old Woman Creek watershed, which has been occupied off and on for the past 10,000 years, was attractive to Indian people because of its well-drained sandy soil and its strategic location between the forest and lakeshore. The site's location provided protected access down the valley and through the estuary to the lake for fishing and commerce, and immediate entry to nearby upland forests with their rich harvest of plant foods and game (Shane 1992).

Then, about three thousand years ago, the way of life of Indian people in much of eastern North America began to undergo a fundamental change, partially in response to the cultivation of certain plants for food. Cultivated plant foods supplemented a subsistence economy based on hunting, gathering, and fishing, and by about 900 A.D., Indian farmers became reliant on corn, beans, squash and sunflower for a significant portion of their food. As discussed in Chapter 8, the major village in the Reserve was occupied during the 15th century, the late Woodland Period. Although the villagers farmed corn, it is believed that farming was less important to the village economy than hunting, fishing, or gathering (Shane 1981, 1992).

For nearly 10,000 years man developed and refined methods of successfully exploiting the watershed environment for basic needs. About 5,000 years ago the estuary formed as the level of Lake Erie rose and flooded the valley, thus creating a very productive environment to sustain the Indian population. Although lifeways changed significantly from Paleo-Indians to the American Indians that made contact with the European settlers in the late 1700s, the importance of natural resources in everyday life remained constant. Clay from the soil, plants of the wetlands and forests, fish, birds, and mammals were essential to the survival of all these native cultures (Shane 1992).

Historical Use of the Watershed

In 1795, the Greenville Treaty was signed between the United States and the Ohio Indian tribes. This pact began an era that would see the Indians lose all their Ohio lands to the young American government. In 1805, Almon Ruggles came to the Old Woman Creek area to survey the land for the state of Connecticut. This territory was originally part of lands claimed by England as a result of the French and Indian War. Under a charter from the King of England, Connecticut laid claim to the territory that included all of present-day Erie County and Huron County, which includes the Old Woman Creek watershed. Following the American Revolution, colonies were requested to cede their holdings of western land to the newly formed government. Connecticut agreed to turn over their colonial holdings except for one western tract reserved for the state. During the American Revolution many residents of Connecticut had lost their property. In return for damages suffered (mainly by fire), the state agreed to give land to these citizens in lieu of monetary payment. In 1792 the westernmost 500,000 acres of the "Connecticut Western Reserve" was set aside as "The Firelands," to be divided among some 1,870 claimants.

Early Firelands pioneers found the land surrounding Old Woman Creek covered by dense forests of oak, chestnut, hickory, ash, walnut, sycamore, and whitewood (tuliptree). The generally rich, sandy soils in Berlin and Huron Townships were well suited for agriculture and the climate, moderated by the proximity of Lake Erie, was favorable for fruit farming. Fruit trees were first brought to the Old Woman Creek area from Canada in 1812, and became an important crop in the years to follow (Gordon 1966,1969).

During the 19th century, historical records indicate that saw mills, sandstone quarries (Figure 9.1), grist mills and at least one salt well were situated within the Old Woman Creek watershed. Small fruits such as strawberries, raspberries, and grapes were also commercially imported to this region throughout the next hundred years. Hardwood timber, particularly oak, was sought by the ship building industry in nearby Huron. This community was the largest steamship building site on the Great Lakes in 1830 (Herdendorf & Schuessler 1993).

By 1874, most of the land surrounding Old Woman Creek had been cleared, timber removed, and ditches opened to drain agricultural lands (Figures 9.2 to 9.4). These factors contributed to annual flooding of the creek, rendering its flood plain "worthless" to farmers (Wright 2000).

The last commercial ventures in the land that would become Old Woman Creek Reserve or estuary began about 1880 on Star Island in the middle of the creek. At this time, the island was accessible from the mainland in dry weather via a road through the cat-tail marsh. Charles Hardy is believed to have bought the 10-acre island from James Anderson and during the winters of the next five years, proceeded to remove the virgin hardwood timber. Then, in 1899, Martin Daniels purchased the island, built a house and barn, and raised his family there. The island was cultivated in strawberries. raspberries, grapes, red currants and tree fruits. The Daniels' family business venture met quick success. Through the early 1900s, the Daniels' expanded their business to include a retail outlet on the island where tourists could buy grapes, berries, and honey. With the approach of the "Great Depression" years, fruit prices dropped and the family was forced out of business and left their island farm (Wright 1981).

The immediate vicinity surrounding Old Woman Creek National Estuarine Reserve has remained relatively undisturbed since the island occupation in

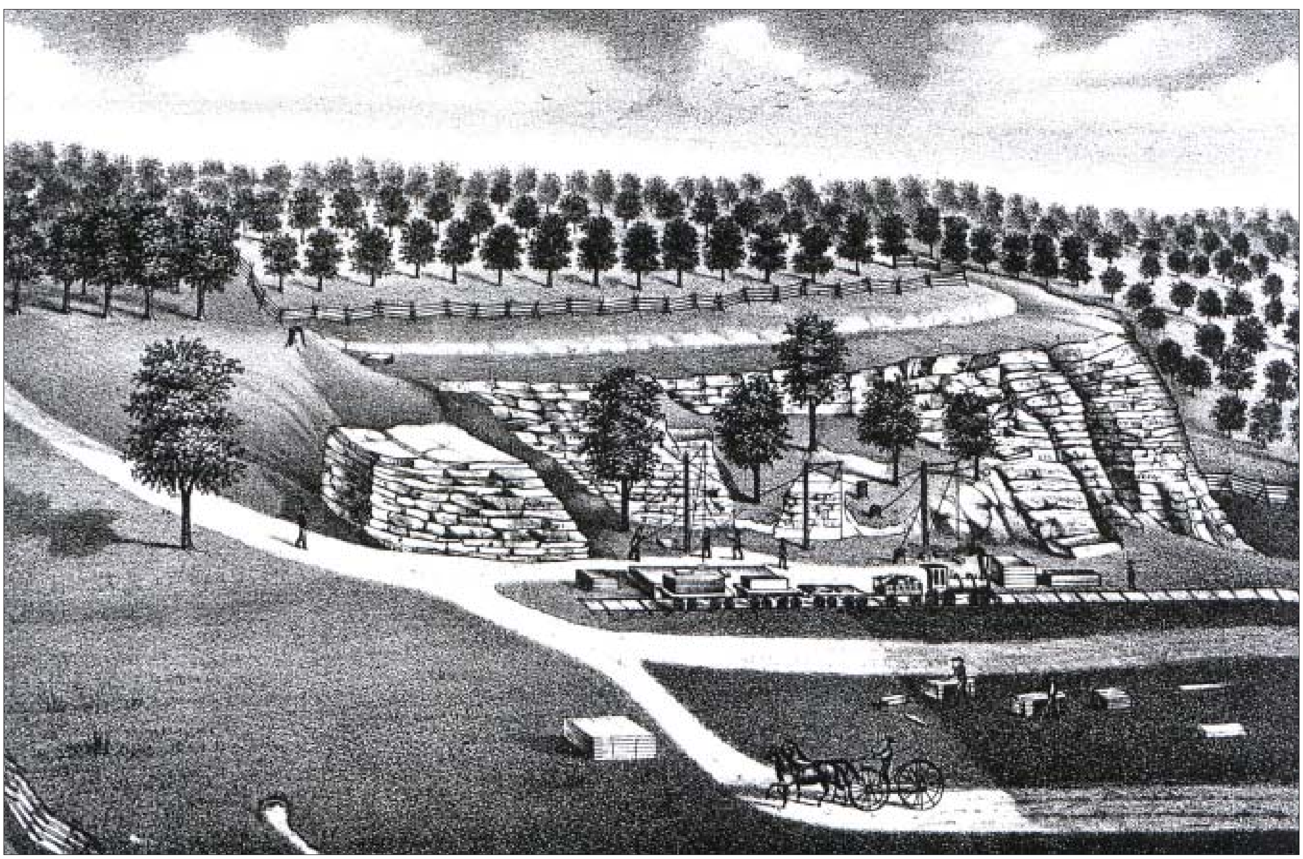


Figure 9.1. Sandstone quarry on the Berea Escarpment at Berlin Heights (Stewart & Page 1874).

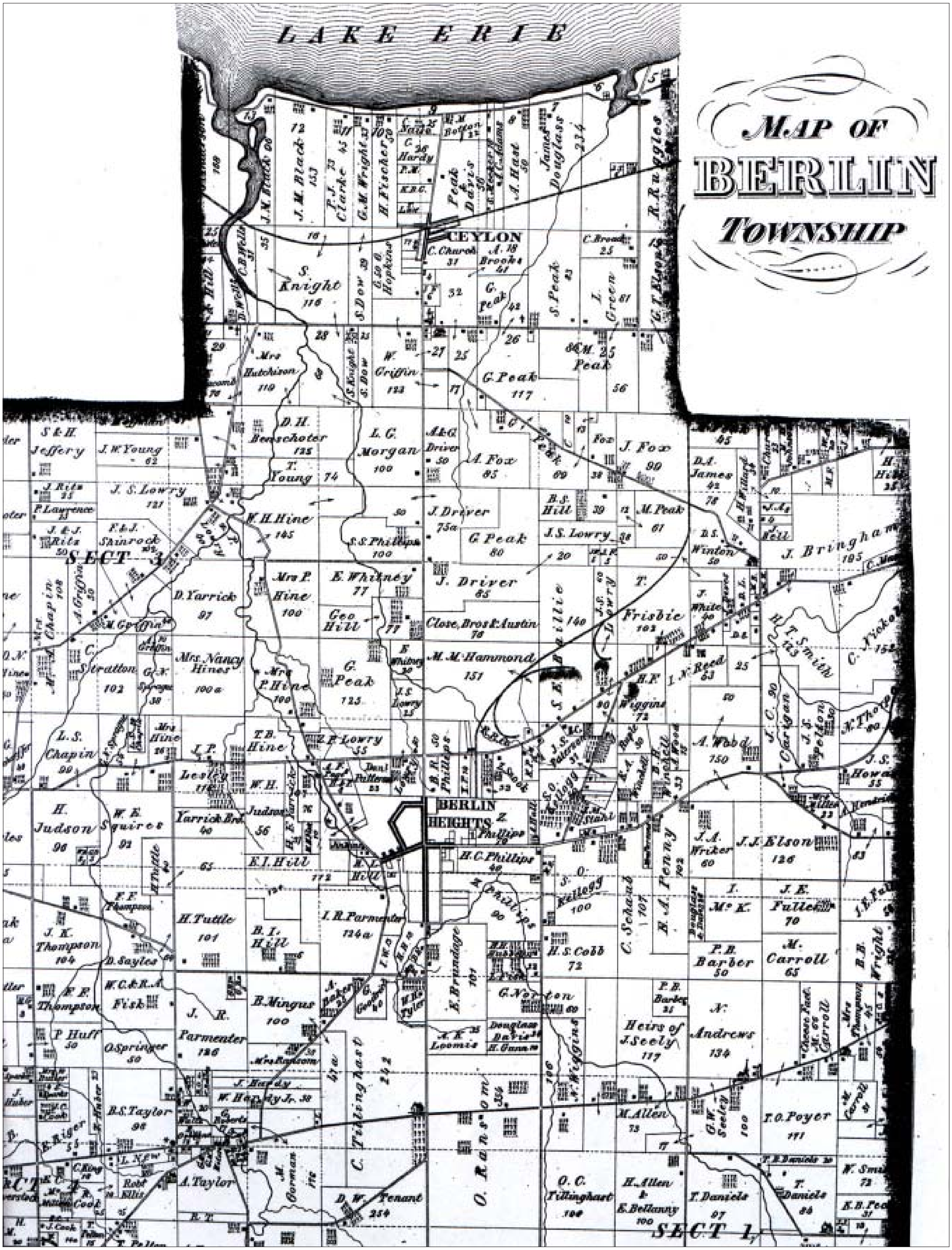


Figure 9.2. Property map of Berlin Township showing location of Old Woman Creek at upper left (Stewart & Page 1874).

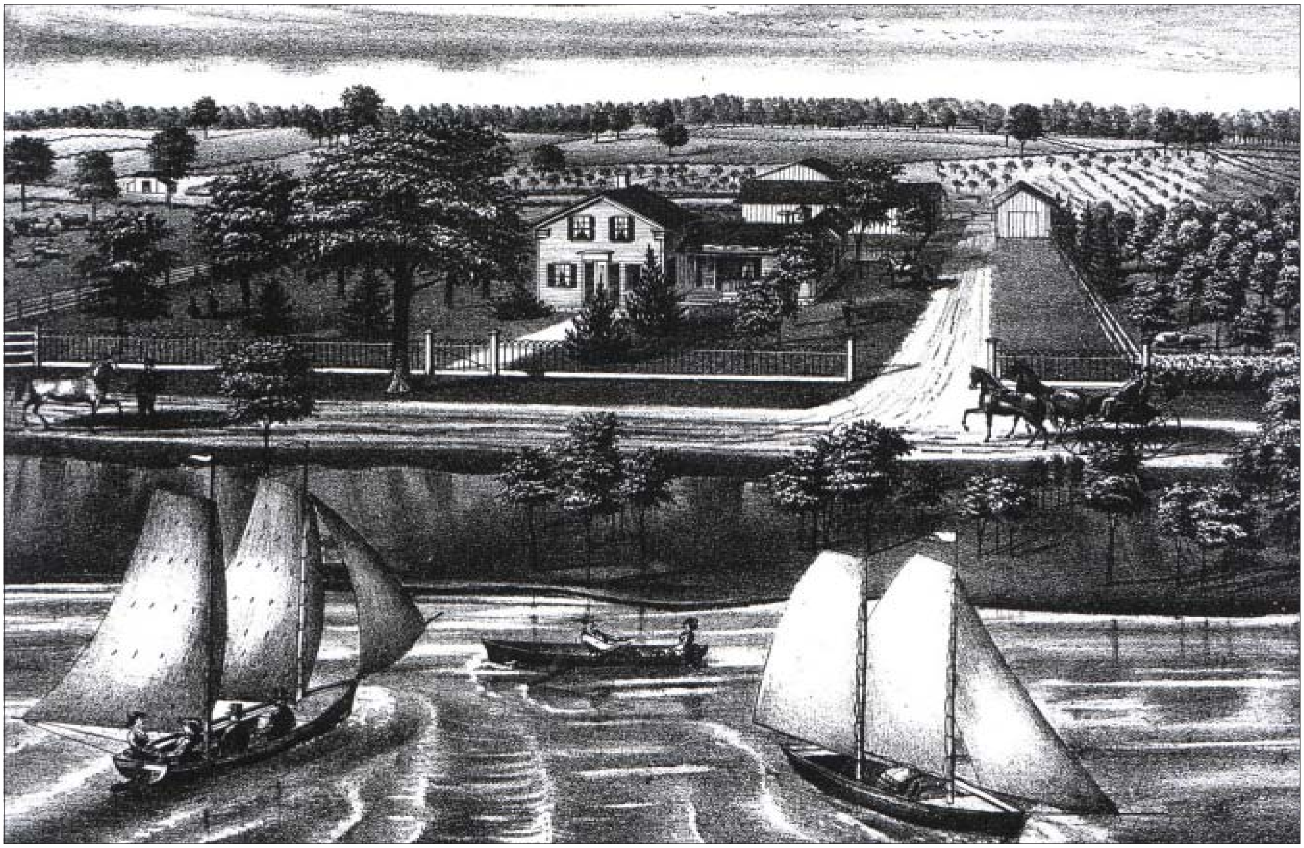


Figure 9.3. James Douglass house on lakeshore 3 km east of Old Woman Creek (Stewart & Page 1874).

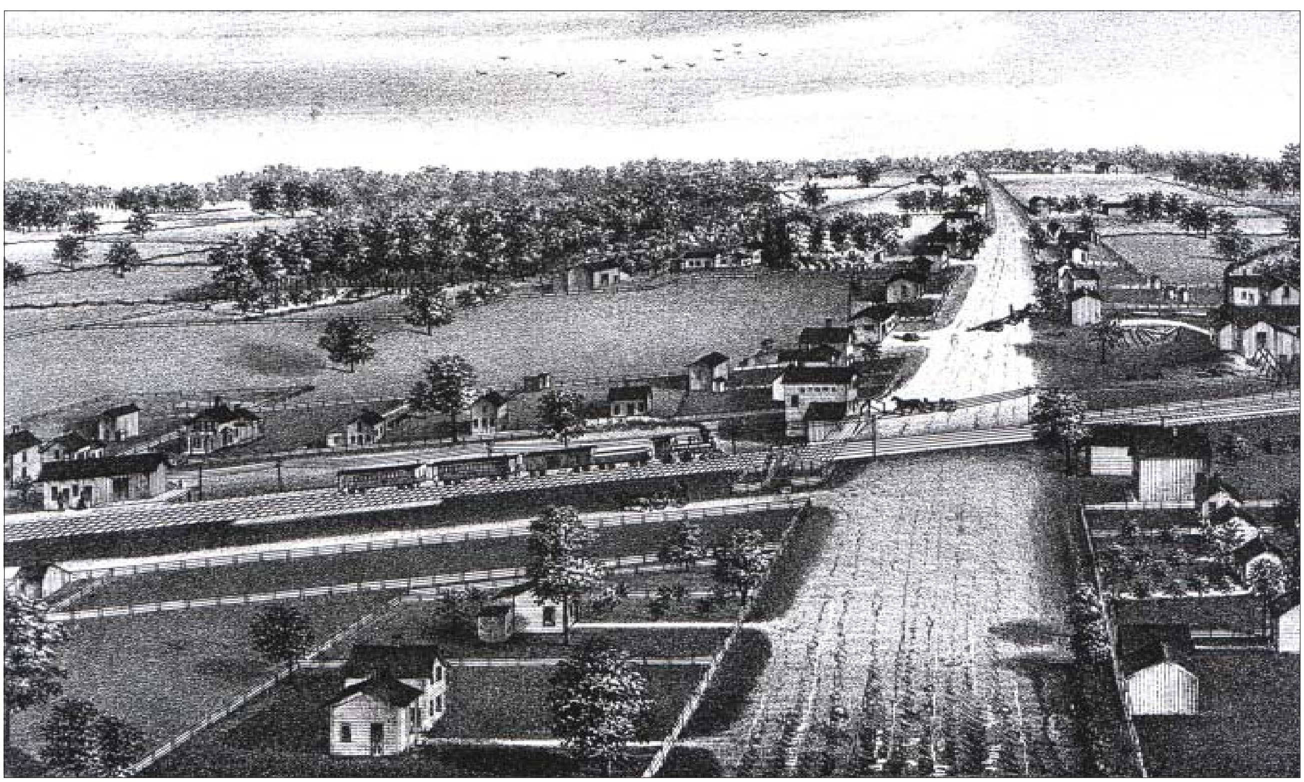


Figure 9.4. Aerial view of Ceylon showing Old Woman Creek valley at upper left (Stewart & Page 1874).

1929 for several reasons. Perhaps the most important factor has been the attitude of landowners controlling the critically located properties near the creek mouth. Three groups of people resisted the pressures from developers who would have altered the natural character of Old Woman Creek in pursuit of recreational activities and urban expansion.

The Anderson family owned the land along the estuary's western bank from 1839 until the Ohio Department of Natural Resources purchased a portion of it for the Reserve. The upland portion of this property was farmed throughout their ownership. The northernmost property on the west bank of Old Woman Creek Estuary is the Hartley homestead. This property has been in the family since the middle 1800s. Fruit and vegetable farming was the primary family vocation for two generations, and today a third generation of the Hartley family resides on the shores of the estuary. The Hartley family's strong feeling of tradition has been their incentive for maintaining the land as it is.

The third property owner instrumental in keeping Old Woman Creek in a relatively undisturbed condition was Oberlin College Beach Association. About 1917, Oberlin College trustees purchased several acres along the eastern banks of the creek. Cottages were built on the lakeshore portion of their property, but the southern portion along the estuary was preserved in its natural condition and has been managed as a private nature preserve throughout their ownership. The concern for the area's natural features by these landowners was a key in attracting ODNR to Old Woman Creek. It was through the combined efforts of local civic organizations, environmental groups, and interested citizens that Old Woman Creek National Estuarine Research Reserve became a reality.

LAND USE IN THE 20TH CENTURY

In conjunction with the Institute for Resource Information Systems of Cornell University, Old Woman Creek NERR conducted a comparative study of land use patterns within the Old Woman Creek watershed for the years 1937 and 1993 (Herdendorf 1997a). From the earliest (1937) and the most recent (1993) aerial photographs of the watershed, some 30 land use categories were discriminated and plotted for the entire 69 km^2 watershed. Once plotted, the area of each of the hundreds of individual land use polygons was determined with a polar planimeter. The results of these determinations, summarized by political subdivision (townships and counties), are presented in Tables 9.1 and 9.2. A comparison of the two time periods is presented in Table 9.3.

The most notable changes occurred in the agricultural and forest land categories. While active farm lands decreased by nearly 24% in the 56-year period, forested lands rose by over 16%. Presumably about 70% of the farm land that was vacated in the intervening years was permitted to return to woodlands. Other modest gains occurred in the residential and transportation categories, approximately 3% each. From a total area standpoint, human land use of the watershed was less intense in the early 1990s than it was in the late 1930s. However, from an ecological viewpoint, the modern application of fertilizers, pesticides, and herbicides in the 1990s may overshadow this apparent environmental improvement.

CURRENT LAND USE CONCERNS

Today, in the year 2003, the major land use in the Old Woman Creek watershed is agriculture (Figures 3.7 and 9.5). The fertile silt and sand loam soils of the area, complimented by the prolonged growing season due to the "lake effect" (see Chapter 4) are currently producing high yields of corn, soybeans, wheat, orchard fruit, and other produce associated with "truck farms." The economy of the area, however, is entering a transitional stage, as agricultural lands are being preempted by the outward growth of the city of Huron.

The area immediately surrounding the Old Woman Creek Reserve is undergoing rapid growth in planning for and construction of residential subdivisions and light industry. This development has been brought about, in large part, by recent improvements in the transportation infrastructure. With the completion of 4-lane State Route 2 in the late 1980s, with access ramps on both the east and west sides of the estuary, the lower Old Woman Creek watershed is becoming an attractive residential and commercial site. This "attractiveness" has already become a management-boundary-water quality concern for the Reserve. Maintaining the integrity of the natural estuarine community will continue to be a problem for future Reserve operations and management. Of particular concern will be: (1) surface runoff from adjacent and watershed-wide development, (2) protection of the Reserve from trespass in areas other

TABLE 9.1. OLD WOMAN CREEK WATERSHED LAND USE BY POLITICAL SUBDIVISION: 1937

Land Use (Code)	Berlin Twp.	Florence Twp.	Huron Twp.	Milan Twp.	Erie County	Townsend Twp.	Wakeman Twp.	Huron County	Watershed Total	Watershed Percent (%)
AGRICULTURE										
Cropland/crop-pasture (Ac)	2,943.3 ha	106.5 ha	100.8 ha	79.9 ha	3,230.5 ha	1,072.4 ha		1,072.4 ha	4,302.9 ha	62.7
Horticulture (Ah)										
Orchard (Ao)	321.6	8.7		1.7	332.0	9.3	0.5 ha	9.8	341.8	5.0
Permanent pasture (Ap)	939.3	40.4	3.9	7.4	991.0	216.0		216.0	1,207.0	17.6
High-intensity cropland (At)										
Vineyard (Av)	1.3				1.3				1.3	<0.1
Agriculture inactive (Ai)	152.9	3.5		8.6	165.0	20.3	4.1	24.4	189.4	2.8
COMMERCIAL										
Commercial strip (Cs)	1.6				1.6				1.6	<0.1
COMMUNICATION										
Service facilities (Tt)										
EXTRACTIVE										
Stone quarry (Es)										
Mining, underground (Eu)										
FOREST LAND										
Brush cover, <10 m (Fc)	191.8			3.1	194.9	34.6	2.1	36.7	231.6	3.4
Forest, >10 m tall (Fn)	281.6			0.8	282.4	43.7		43.7	326.1	4.8
INDUSTRIAL										
Light manufacturing (Il)	0.7				0.7				0.7	<0.1
NON-PRODUCTIVE										
Sand, beach (Ns)	0.1				0.1				0.1	<0.1
PUBLIC										
All categories (P)	8.2				8.2				8.2	0.1
RECREATION										
Outdoor (Or)										

TABLE 9.1. OLD WOMAN CREEK WATERSHED LAND USE BY POLITICAL SUBDIVISION: 1937 (cont'd)

Land Use (Code)	Berlin Twp.	Florence Twp.	Huron Twp.	Milan Twp.	Erie County	Townsend Twp.	Wakeman Twp.	Huron County	Watershed Total	Watershed Percent (%)
RESIDENTIAL										
Medium density (Rm)	36.0				36.0				36.0	0.5
Low density (Rl)				12.5				12.5	12.5	0.2
Residential strip (Rs)										
Migrant labor camp (Rc)										
TRANSPORTATION										
Railroad (Tr)	20.9		1.4		22.3	1.2		1.2	23.5	0.3
Highway, limited access (Th)										
Highway, primary (Tp)	19.3				19.3	1.4		1.4	20.7	0.3
Highway, secondary (Ts)	57.0	1.1	0.8	1.4	60.3	12.7	0.4	13.1	73.4	1.1
URBAN										
Urban inactive (Ui)										
WATER RESOURCES										
Artificial/farm pond (Wc,Fp)	0.1				0.1				0.1	<0.1
Freshwater estuary (We)	41.0				41.0				41.0	0.6
Natural (Wn)										
Streams (Ws)	8.7				8.7				8.7	0.1
WETLANDS										
Marsh/shrub wetland (Wb)	10.5				10.5	0.5		0.5	11.0	0.2
Wooded wetland (Ww)	22.2				22.2				22.2	0.3
TOTAL	5,070.6	160.2	106.9	102.9	5,440.6	1,412.1	7.1	1,419.2	6,859.8	100.0

Data Sources:

Institute for Resource Information System 1937 Old Woman Creek watershed, Huron Ohio: 1937 land use/land cover. Cornell University, Ithaca, New York. 1 map.

U.S. Geologocal Survey: 7.5 Topographic quadrangle maps for Berlin Heights, Ohio (1979); Clarksfield, Ohio (1972); Huron, Ohio (1979); Milan, Ohio (1969); Vermilion West, Ohio (1979).

Land Use Code Detail:

COMMERCIAL

Commercial strip (Cs) — <33% intermixture of residential strip

RESIDENTIAL

Medium density (Rm) — 15-30 m frontage

Low density (Rl) — >30 m frontage

Residential strip (Rs) — <33% intermixture of commercial strip

TABLE 9.2. OLD WOMAN CREEK WATERSHED LAND USE BY POLITICAL SUBDIVISION: 1993

Land Use (Code)	Berlin Twp.	Florence Twp.	Huron Twp.	Milan Twp.	Erie County	Townsend Twp.	Wakeman Twp.	Huron County	Watershed Total	Watershed Percent (%)
AGRICULTURE										
Cropland/crop-pasture (Ac)	2,381.3 ha	138.8 ha	67.6 ha	94.8 ha	2,682.5 ha	1,228.2 ha	7.1 ha	1,235.3 ha	3,917.8 ha	57.1
Horticulture (Ah)	2.9				2.9				2.9	<0.1
Orchard (Ao)	180.4				180.4				180.4	2.6
Permanent pasture (Ap)	209.0				209.0	22.0		22.0	231.0	3.4
High-intensity cropland (At)	31.5				31.5				31.5	0.5
Vineyard (Av)										
Agriculture inactive (Ai)	122.4				122.4	8.1		8.1	130.5	1.9
COMMERCIAL										
Commercial strip (Cs)	8.8				8.8	2.7		2.7	11.5	0.2
COMMUNICATION										
Service facilities (Tt)	6.6				6.6	0.5		0.5	7.1	0.1
EXTRACTIVE										
Stone quarry (Es)						10.2		10.2	10.2	0.1
Mining, underground (Eu)						0.6		0.6	0.6	<0.1
FOREST LAND										
Brush cover, <10 m (Fc)	415.4	2.7	12.5	0.5	431.1	40.0		40.0	471.1	6.9
Forest, >10 m tall (Fn)	1,116.3	20.6	1.0	4.4	1,142.3	84.0		84.0	1,226.3	17.9
INDUSTRIAL										
Light manufacturing (Il)	7.7			0.7	8.4				8.4	0.1
NON-PRODUCTIVE										
Sand, beach (Ns)	2.1				2.1				2.1	<0.1
PUBLIC										
All categories (P)	12.8		4.0		16.8				16.8	0.2
RECREATION										
Outdoor (Or)	14.8				14.8				14.8	10.2
RESIDENTIAL										
Medium density (Rm)	113.6				113.6				113.6	1.7
Low density (Rl)	119.0			3.2	122.2	1.0		1.0	123.2	1.8
Residential strip (Rs)	14.6				14.6				14.6	0.2
Migrant labor camp (Rc)	1.8				1.8				1.8	<0.1

TABLE 9.2. OLD WOMAN CREEK WATERSHED LAND USE BY POLITICAL SUBDIVISION: 1993 (cont'd)

Land Use (Code)	Berlin Twp.	Florence Twp.	Huron Twp.	Milan Twp.	Erie County	Townsend Twp.	Wakeman Twp.	Huron County	Watershed Total	Watershed Percent (%)
TRANSPORTATION										
Railroad (Tr)	15.3		1.1		16.4	1.2		1.2	17.6	0.3
Highway, limited access (Th)	67.5		11.7	2.9	82.1				82.1	1.2
Highway, primary (Tp)	19.3				19.3	1.4		1.4	20.7	0.3
Highway, secondary (Ts)	57.0	1.1	0.8	1.4	60.3	12.7	0.4	13.1	73.4	1.1
URBAN										
Urban inactive (Ui)	5.4				5.4				5.4	0.1
WATER RESOURCES										
Artificial/farm pond (Wc,Fp)	17.7				17.7	3.2		3.2	20.9	0.3
Freshwater estuary (We)	51.9				51.9				51.9	0.7
Natural (Wn)	1.3				1.3				1.3	<0.1
Streams (Ws)	12.7				12.7				12.7	0.2
WETLANDS										
Marsh/shrub wetland (Wb)	22.7	0.8			23.5	0.7		0.7	24.2	0.4
Wooded wetland (Ww)	31.3			1.7	33.0				33.0	0.5
TOTAL	5,063.1	164.0	98.7	109.6	5,435.4	1,416.5	7.5	1,424.0	6,859.4	100.0

Data Sources:
Institute for Resource Information System 1993 Old Woman Creek watershed, Huron Ohio: 1993 land use/land cover. Cornell University, Ithaca, New York. 1 map.
U.S. Geologocal Survey: 7.5 Topographic quadrangle maps for Berlin Heights, Ohio (1979); Clarksfield, Ohio (1972); Huron, Ohio (1979); Milan, Ohio (1969);Vermilion West, Ohio (1979).

Land Use Code Detail:

COMMERCIAL
Commercial strip (Cs) <33% intermixture of residential strip

RESIDENTIAL
Medium density (Rm) 15-30 m frontage
Low density (Rl) >30 m frontage
Residential strip (Rs) <33% intermixture of commercial strip

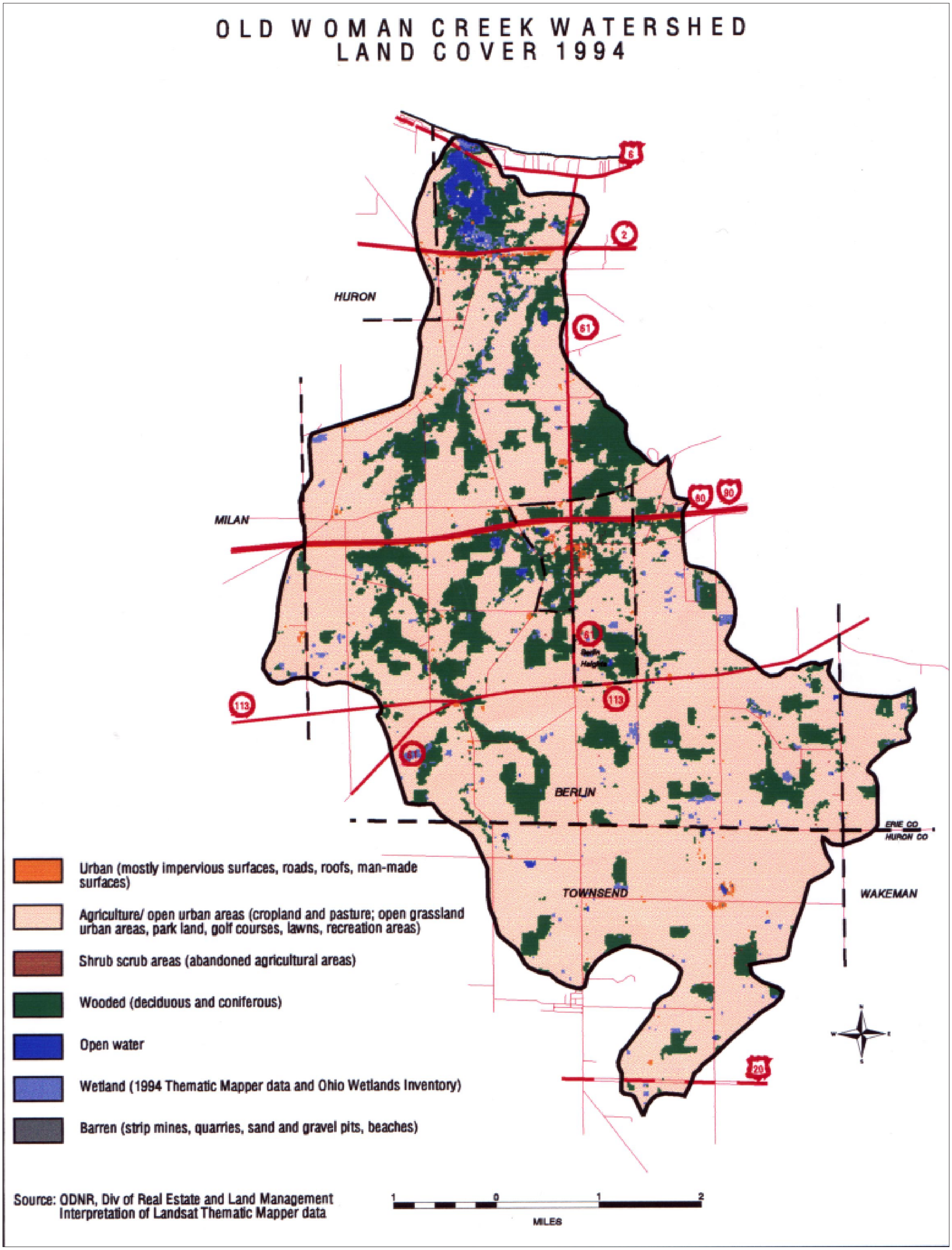


Figure 9.5. Land use patterns in Old Woman Creek watershed.

TABLE 9.3. COMPARATIVE CHANGES IN LAND USE FOR OLD WOMAN CREEK WATERSHED: 1937 AND 1993

Land Use Type	1937 Percent (%)	1993 Percent (%)	Percent Change (%)
Agriculture			
Cropland	66.3	59.5	-6.8
Orchard & Vineyard	5.1	2.6	-2.5
Pasture	17.9	3.4	-14.5
	89.3	65.5	-23.9
Commercial & Manufacturing	<0.1	0.5	+0.5
Forest	8.3	24.8	+16.5
Residential	0.8	4.2	+3.4
Water	1.2	2.1	+0.9
Transportation	0.3	2.9	+2.6
TOTAL	100.0	100.0	

than designated access points, (3) aesthetic pollution, such as visual, lights, and noise, (4) non-point source pollution from certain agricultural practices and failing domestic septic and commercial systems within the watershed, and (5) environmental risks aggravated by increased highway and rail traffic on transportation corridors through the Reserve.

Human Population

Old Woman Creek National Estuarine Research Reserve is located in the coastal area of central Lake Erie in eastern Erie County, Ohio (Figure 9.6). Studies conducted by Holly (1986) indicated that the Research Reserve was part of the Northeast Ohio Urban Field centered on Cleveland. He pointed out that economic and demographic trends in the 1960s and 1970s suggested that Erie County would experience a significant population expansion as a result of increased recreational and retirement use of Lake Erie coast and the dispersal of population away from cities to the east. Holly projected a 4,500-person population increase for the coastal area between Huron and Vermilion, Ohio between 1980 and 1990, and a 12,000-person increase by the year 2005. Therefore, he recommended immediate and long-term actions to preserve the Reserve's natural integrity.

Analysis of recent population data shows that the forecasted increases never materialized, and indeed, the coastal and upper watershed populations decreased from 1980 to 1990. The purpose of the following report

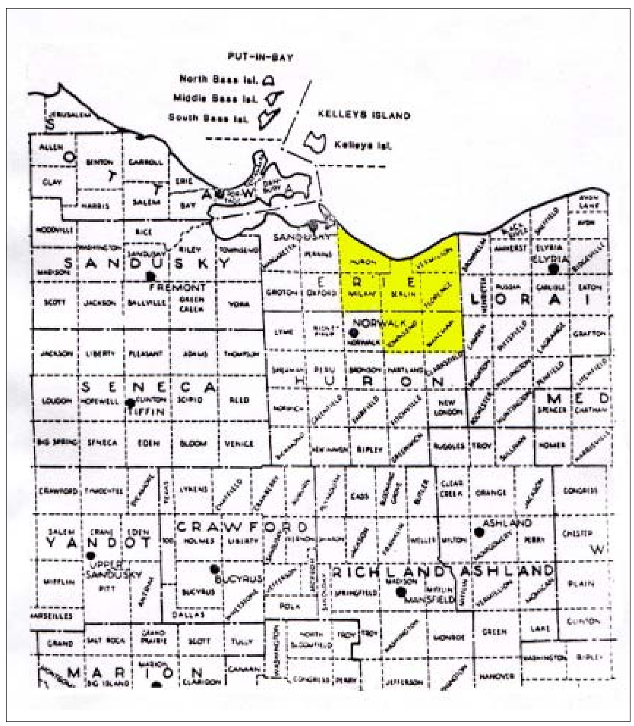


Figure 9.6. Location of political subdivisions surrounding Old Woman Creek watershed. In 1996 the watershed had a population of 33,873 in 11,502 households.

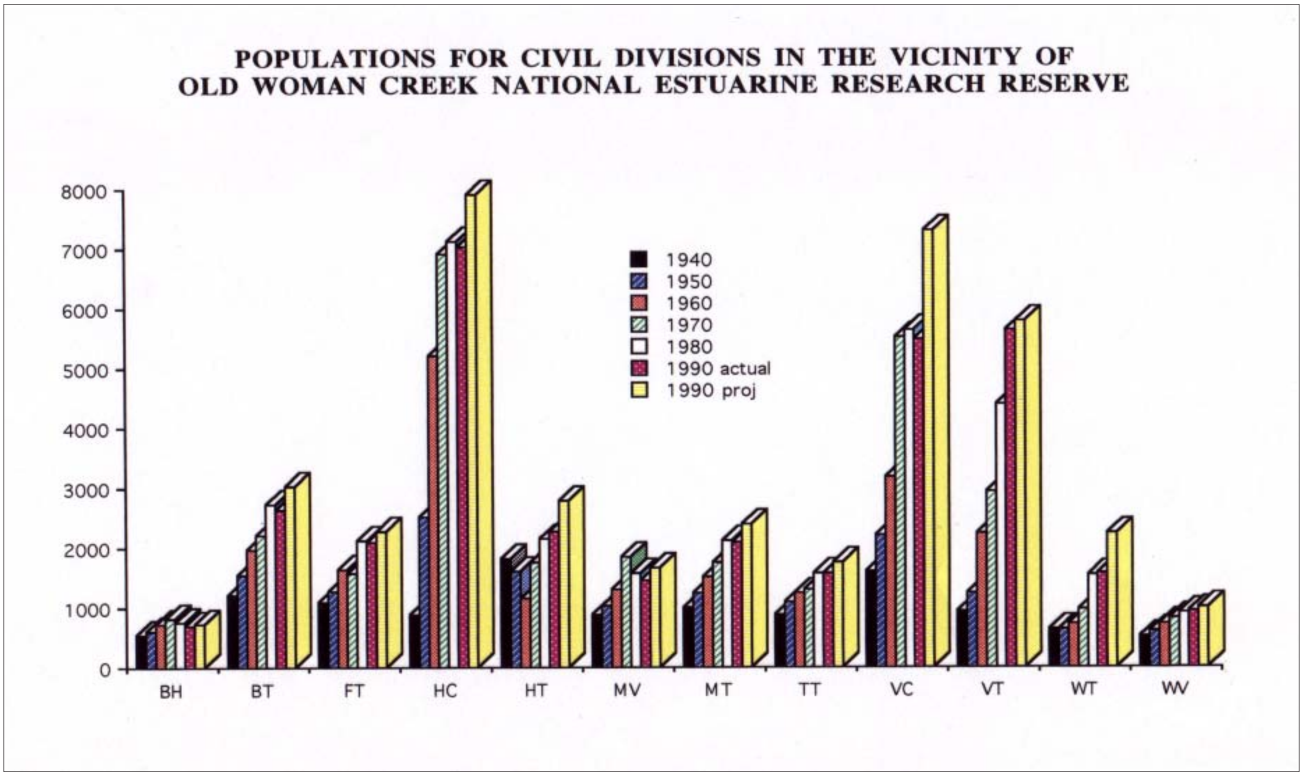


Figure 9.7. Population trends for Old Woman Creek watershed vicinity area from 1940 to 1990.

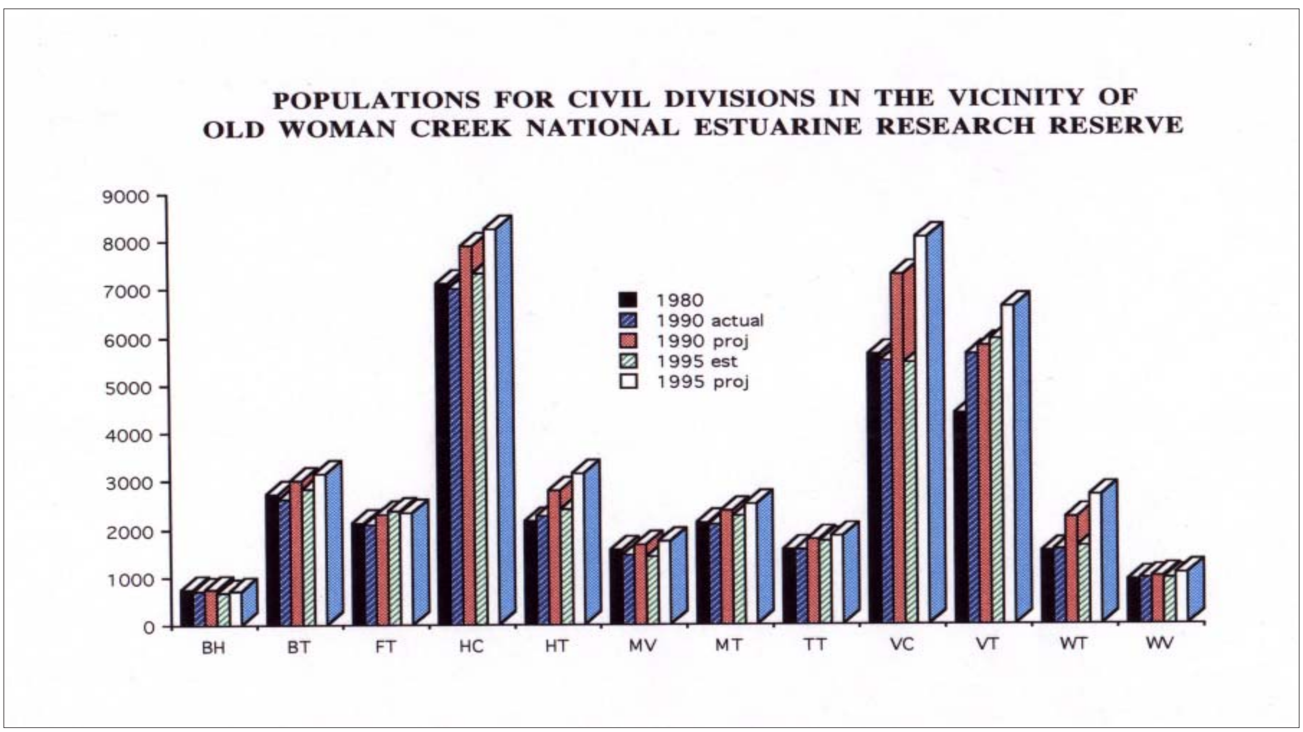


Figure 9.8. Population trends for Old Woman Creek watershed vicinity area from 1980 to 1995.

BH–Berlin Heights; BT–Berlin Township; FT–Florence Township; HC–Huron City; HT–Huron Township; MV–Milan Village; MT–Milan Township; TT–Townsend Township; VC–Vermilion City; VT–Vermilion Township; WT–Wakeman Township; WV–Wakeman Village.

TABLE 9.4. POPULATION SATISTICS FOR CIVIL DIVISIONS SURROUNDING OLD WOMAN CREEK NATIONAL ESTUARINE RESEARCH RESERVE

	1940[1]	1950[1]	1960[1]	1970[1]	1980[1]	1990[1]	1990[2] proj.	1995[3] est.	1995[2] proj.
COASTAL AREAS (ERIE COUNTY)									
Berlin Twp Annex[4]	371	456	583	657	806	777	896	838	937
Huron City	870	2,512	5,197	6,896	7,123	7,067	7,908	7,322	8,269
Huron Twp	1,827	1,605	1,161	1,745	2,156	2,093	2,782	2,393	3,137
Vermilion City	1,616	2,214	3,183	5,500	5,634	5,483	7,207	5,458	8,090
Vermilion Twp	931	1,253	2,256	2,946	4,393	4,051	5,798	4,369	6,610
	5,615	8,040	12,380	17,744	20,112	19,471	24,591	20,380	27,043
UPPER WATERSHEDS (ERIE COUNTY)									
Berlin Twp[5]	833	1,084	1,387	1,565	1,919	1,851	2,132	1,996	2,231
Berlin Heights	552	613	721	828	756	691	733	680	717
Florence Twp	1,102	1,278	1,648	1,576	2,119	2,101	2,286	2,361	2,356
Milan Twp	987	1,233	1,517	1,749	2,129	2,230	2,382	2,257	2,501
Milan Village	719	846	1,076	1,297	1,181	1,056	1,174	1,014	1,162
	4,193	5,054	6,349	7,015	8,104	7,929	8,707	8,308	8,967
UPPER WATERSHEDS (HURON COUNTY)									
Milan Village[6]	156	182	233	565	388	408	504	418	570
Townsend Twp	885	1,105	1,234	1,295	1,571	1,571	1,765	1,745	1,854
Wakeman Twp	647	646	718	964	1,540	1,567	2,248	1,618	2,692
Wakeman Village	522	620	728	822	906	951	1,005	971	1,049
	2,054	2,553	2,913	3,646	4,405	4,497	5,522	4,752	6,165

NOTES:
1. U.S. Bureau of the Census
2. Projections by Holly (1986)
3. Ohio Department of Development, Office of Strategic Research
4. Northern extension of Berlin Twp; estimated for 1940 & 1950 based on 1960 ratio
5. Berlin Twp Annex excluded
6. Estimated for 1940 & 1950 based on 1960 ratio

is to evaluate Holly's population forecasts and to provide a more recent appraisal of population trends.

Population Trends

The human population in the vicinity of Old Woman Creek NERR (coastal area of Erie County from Huron to Vermilion) experienced a sustained high growth rate during the 1940s, 1950s, and 1960s (43%, 54%, and 43% increase per decade, respectively), moderate growth rate in the 1970s (13% increase), and a modest decline in the 1980s (3% decrease) (Figure 9.7; Table 9.4). Population estimates by the Ohio Department of Development for the first half of the 1990s indicate a projected growth rate for the decade of 9% (Figure 9.8; Table 9.4). The population in the upper reaches of the watersheds between Milan and Florence showed a similar trend with less dramatic changes. The number of residents in the townships and villages away from the coast rose in the 1960s (10% increase), continued a substantial growth in the 1970s (16% increase), and declined in the 1980s (2% loss). Likewise population forecasts for the 1990s indicate a decade growth rate of 10% (Figure 9.8, Table 9.4).

The 1996 population of the 14 civil divisions surrounding Old Woman Creek watershed was estimated by the Ohio Department of Development at 33,873 persons (Table 9.5). The average household size for these divisions ranges from 2.8 to 3.2 persons (Erie County Regional Planning Commission 1980, Holly 1986). These factors yield a total of 11,502 households in the region bounded on the northwest by Huron, northeast by Vermilion, and southwest by Milan (Figure 9.6). Concerning environmental impacts, this population has a daily water use of about 21,000 m^3

TABLE 9.5. POPULATION AND ENVIRONMENTAL IMPACTS FOR CIVIL DIVISIONS ADJACENT TO OLD WOMAN CREEK WATERSHED

	Population[1] (1996 est.)	Households[2] (no.)	Water Use[3] (m^3/day)	Sewage[4] (m^3/day)	Traffic[5] (trip/day)
ERIE COUNTY					
Berlin Heights	680	217	386	193	2,170
Berlin Twp	2,882	918	1,637	818	9,180
Florence Twp	2,431	757	1,381	690	7,570
Huron City	7,381	2,636	4,192	2,096	26,360
Huron Twp	2,295	820	1,304	652	8,200
Milan Twp	2,430	821	1,380	690	8,210
Milan Village	1,007	340	572	286	3,400
Vermilion City	5,456	1,801	3,099	1,550	18,010
Vermilion Twp	4,442	1,466	2,523	1,262	14,660
HURON COUNTY					
Milan Village	420	142	239	119	1,420
Townsend Twp	1,817	647	1,032	516	6,470
Wakeman Twp	1,637	583	930	465	5,830
Wakeman Village	995	354	565	283	3,540
TOTAL	33,873	11,502	19,240	9,620	115,020

NOTES:
1. Ohio Department of Development, Office of Strategic Research
2. Household size based on 3.14 persons for Berlin Heights and Berlin Twp; 3.21 for Florence Twp; 2.80 for Huron City and Huron Twp; 2.96 for Milan Twp and Milan Village; 3.03 for Vermilion City and Vermilion Twp; 2.81 for Townsend Twp, Wakeman Twp, and Wakeman Village (Holly 1986)
3. Water use based on per capita use of 0.568 m^3 (150 gal) per day
4. Sewage based on per capita rate of 0.284 m^3 (75 gal) per day
5. Traffic based on 10 vehicular trips per day per household

and generates 10,500 m^3 of sewage. Based on an average daily traffic generation rate of 10 vehicular trips per household (including all local trips for work, shopping, personal activities, mail delivery, trash pick-up, and commercial services), some 120,000 vehicular trips are made in the above described region.

Table 9.6 presents the areas, populations, households, and densities for the 14 civil divisions adjacent to Old Woman Creek watershed. The cities of Vermilion and Huron have the highest population densities at 1,093/km^2 and 574/km^2, respectively and Wakeman Twp. has the lowest density at 25/km^2. As expected, the housing densities are roughly proportional to the population sizes.

POPULATION FORECASTS

Holly (1986) performed a demographic and economic analysis of the region surrounding Old Woman Creek watershed and concluded that eastern Erie County lies in the path of the population expansion resulting from increased recreational and retirement use of the Lake Erie coast and the general dispersal of population away from central cities, such as Cleveland and Lorain. He predicted that Old Woman Creek National Estuarine Research Reserve will be affected by this development, necessitating intermediate and long-term forecasting and planning to preserve the Reserve as a research and interpretive natural area.

TABLE 9.6. POPULATION AND HOUSING DENSITY FOR CIVIL DIVISIONS ADJACENT TO OLD WOMAN CREEK WATERSHED

	Population[1] (1996 est.)	Households[2] (no.)	Area[3] (km^2)	Population Density[4]	Household Density[5]
ERIE COUNTY					
Berlin Heights	680	217	4.03	168.7	53.8
Berlin Twp	2,882	918	73.94	39.0	12.4
Florence Twp	2,431	757	66.52	36.5	11.4
Huron City	7,381	2,636	12.85	574.4	205.1
Huron Twp	2,295	820	47.25	48.6	17.4
Milan Twp	2,430	821	63.49	38.3	12.9
Milan Village	1,007	340	1.80	559.4	188.9
Vermilion City	5,456	1,801	4.99	1,093.4	360.9
Vermilion Twp	4,442	1,466	50.92	87.2	28.8
HURON COUNTY					
Milan Village	420	142	1.43	293.7	99.3
Townsend Twp	1,817	647	66.01	27.5	9.8
Wakeman Twp	1,637	583	64.40	25.4	9.1
Wakeman Village	995	354	1.97	505.1	179.7
TOTAL	33,873	11,502	495.60		
			MEAN	68.3	23.2

NOTES:
1. Ohio Department of Development, Office of Strategic Research
2. Household size based on 3.14 persons for Berlin Heights and Berlin Twp; 3.21 for Florence Twp; 2.80 for Huron City and Huron Twp; 2.96 for Milan Twp and Milan Village; 3.03 for Vermilion City and Vermilion Twp; 2.81 for Townsend Twp, Wakeman Twp, and Wakeman Village (Holly 1986)
3. Erie Regional Planning Commission (1970); Erie County Office of Engineer; Huron County Highway Dept.
4. Population density in number of residents per km^2
5. Household density in numbers of home sites per km^2

The forecasts made by Holly (1986) indicated steady increases in population in the townships and cities contiguous to and near the Research Reserve, with a 12,000-person increase along the coastal area from Huron to Vermilion for the 25-year period of 1980 to 2005. Rural, agricultural areas away from the coast, in the upper reaches of the watershed, were predicted to increase steadily, but more slowly than rural, non-farm areas. In both the coastal area and the upper watershed the population increases were predicted to result in a steady conversion of agricultural and vacant land to residential use, with attendant increases in water use, sewage generation, and local traffic (Table 9.5). The completion of the Ohio Route 2 Bypass linking the cities east of Vermilion to the cities west of Huron (1989) was expected to increase accessibility to the Old Woman Creek watershed, making it more desirable for residential development.

Forecasting population trends is a risky venture. The model developed by Holly (1986) forecasted a population increase of 22.3% (4,479 individuals) between 1980 and 1990 for the coastal area from Huron to Vermilion and a population increase for the upper watersheds from Milan to Florence of 7.4% (603 individuals). In actuality, the population in both sectors declined in the 10-year period between 1980 and 1990: -3.2% (-614 individuals) for the coastal area and -2.3%

(-179 individuals) for the upper watersheds based on U.S. Bureau of the Census statistics (Figure 9.5; Table 9.4). Population estimates for 1995, generated by the Ohio Department of Development, show some recovery in both sectors, but far below the projections of Holly (1986).

The present authors have attempted to determine what went wrong with the model developed by Holly (1986). The model assumptions led to a forecast of continued, and even accelerated, population growth in the region for the 1980s and beyond. The model failed to predict a leveling-off and modest decline in the population at a rate of about 0.3 % per year for the last decade. Holly considered eastern Erie County to lie within the "commuting shed" of Cleveland by virtue of highway connections. He further speculated that by the end of the century Erie County would attain sufficient metropolitan character and functional integration with urban areas to the east, through commuter traffic, that it would be incorporated into the Lorain-Elyria Statistical Metropolitan Area (SMA).

The moderate population increases in the first half of the 1990s indicate that Holly may have been a decade or two early with his expansion forecasts, but this still does not explain the population decline of the 1980s. A more plausible explanation may be that the rapid increases of the 1960s and 1970s reached a temporary saturation point in the 1980s as available infrastructure resources were being taxed to their limit and most of the prime development land been secured for residential conversion. The opening of the Ohio Route 2 Bypass at the end of the decade, improvements in water/sewage technology for remote locations, and economic prosperity appear to have stimulated a new round of development in the 1990s.

RELATIONSHIP OF LAND USE TO SOIL EROSION

Evaluating the nature and extent of soil erosion in Old Woman Creek watershed is fundamental to developing management strategies for controlling stream-borne sediment and sediment-bound nutrients. Matisoff et al (2002a) found that various portions of the Old Woman Creek watershed contribute sediment at different rates, of different size and composition, and with different associated nutrients and contaminants. These differences in rates of contribution and sediment properties result from differences in geological processes contributing sediment (e.g. surface wash, rill formation, and landslides) and differences in land usage (e.g. forested, prairie, agricultural, and urban). Standard sediment budget calculations (Dietrich and Dunne 1978) provide an initial indication of sediment production, but Matisoff et al. (2002a) used radionuclide soil tracers to achieve a more detailed discrimination of sediment sources. Characterizing soils and suspended sediment using radionuclide tracers permitted these researchers to identify sediment source areas and land uses that are problematic. This allowed for targeting of appropriate sediment management practices within the watershed.

The radionuclide profiles in agricultural no-till and tilled soils in the watershed exhibited considerable differences from undisturbed soil on Star Island located near the center of the estuary. The soils on Star Island showed a surface or near surface peak of ^{210}Pb (lead) and ^{137}Cs (cesium) while the tilled soils were largely homogeneous, due to plowing (Figure 9.9). The no-till agricultural soils were also significantly mixed by previous plowing, but rebuilding of ^{210}Pb at the surface was indicated. Radionuclide ^{210}Pb (half-life=22.3 years) is a natural decay product of ^{238}U (uranium) through a series of reactions and eventually escapes to the atmosphere; ^{7}Be (beryllium) (half-life=53.3 days) is continually produced in the upper atmosphere by cosmic rays bombarding nitrogen and oxygen. Both of these radionuclides continually reach the surface of the earth, especially during thunderstorms. Whereas, ^{137}Cs (half-life=30.2 years) in soil is mostly the result of atmospheric nuclear bomb testing during the 1960s and 1970s. Because ^{7}Be has such a short half-life and is continually being added at the land surface, its profile is relatively consistent in all land use conditions (Figure 9.9). This radionuclide has proved very useful as an indicator of sediment transport distances (Bonniwell 2001, Matisoff et al. 2002b).

Matisoff et al. (2002a) observed that sediment eroded from a soil has a specific signature corresponding to the tillage practice and the depth of erosion. Thus, radionuclide signatures in suspended sediment of Old Woman Creek and the estuary can: (1) provide a means of tracing particles eroded from the land surface, (2) identify soil sources, and (3) be used to quantify the erosion. The study showed that runoff from tilled portions of the watershed had a

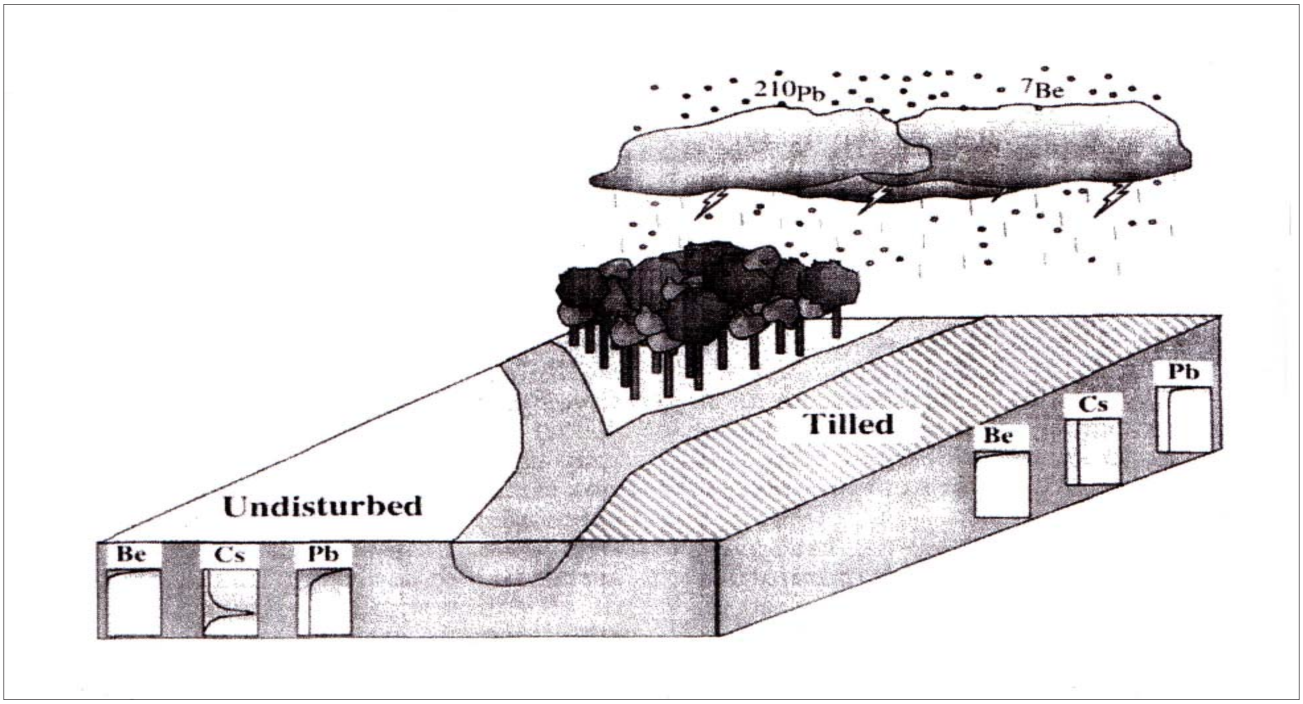


Figure 9.9. Generalized diagram illustrating the distribution of ^{7}Be, ^{210}Pb, and ^{137}Cs in soils under different tillage practices to a depth of 10 to 30 cm (Matisoff et al. 2002b).

higher sediment yield than their no-till counterparts in response to a thunderstorm, at a ratio of approximately 10:1. The tilled agricultural fields in the upper reaches of the watershed provide a disproportionate amount of suspended sediment delivered to the estuary. This investigation suggests that (1) erosion control initiatives may be most beneficial at upland locations near the head of the drainage in the watershed where erosion is the greatest and (2) improved land management practices in these areas will produce results more quickly in the receiving waters.

In addition to the identification of sediment sources, the determination of sediment transport distances is important to the understanding of sediment fluxes in the watershed. While the identification of sources allows recognition of regions or land use practices that produce large amounts of sediment (and associated nutrients and pollutants), the determination of sediment transport distances permits estimation of which areas of the watershed contribute sediment to receiving waters, i.e. Old Woman Creek estuary and Lake Erie. In addition, Matisoff et al. (2002b) used radionuclide to successfully trace particle transport within the watershed. Because of the relatively long transport distances calculated from this investigation—in relation to the length of the stream channels in the Old Woman Creek drainage basin—the majority of the fine-grained sediment that erodes from the watershed is most likely transported the entire length of the creek and delivered to the estuary and Lake Erie. These findings also show that erosion control methods implemented in the portions of the watershed where erosion is greatest will be reflected rapidly in the receiving water.

Livestock Facilities

Waste from domestic and farm animals in the watershed can be a significant source of water pollution, especially nutrients and disease-causing bacteria and viruses (Courter 1995). Old Woman Creek NERR personnel undertook a demonstration project in 1995 along the upper reaches of Old Woman Creek to determine the impact to stream water quality of various methods of handling animal wastes (Figure 9.10). The project looked at two facilities in Berlin Township where animal wastes were discharged to the west branch of Old Woman Creek (Figure 9.11). The first facility was a hog farm that contained a stabilizing lagoon into which hog wastes were placed before being discharged into the stream. The second facility was a cattle barn located about 0.5 km downstream from the holding pond at the first facility. The cattle barn had no waste control mechanisms, thus animal wastes were discharged directly to the stream by surface runoff. A series of stations was established about every 200 m along the stream at the following stations:

Station A — 100 m above (upstream) hog lagoon (control station)
Station B — 100 m below hog waste lagoon
Station C — 300 m below hog waste lagoon
Station D — 100 m above cattle barn
Station E — 100 m below cattle barn
Station F — 300 m below (downstream) cattle barn

The prime objective of the study was to measure selected water quality parameters following a major rainfall event, thereby quantifying the runoff impact of these livestock facilities on the stream. A rainstorm event occurred in May 1995 which provided the opportunity to determine the relative impact of these facilities on stream water quality. The parameters measured included coliform bacteria, streptococcus bacteria, ammonia, and total phosphorus (P). Measurements commenced at the initiation of the storm and continued at various intervals for 75 hours. Results of measurements are presented in Figures 9.12 to 9.15.

The data graphed in these figures indicates a dramatic difference in water quality downstream of the two livestock facilities. For example, the maximum coliform bacteria count at the station below the hog waste lagoon (B) was only 270 cells/cc, while at the station below the cattle barn (E) the coliform count reached 7,300 cells/cc. Similarly, streptococcus bacteria at the hog facility reached a maximum of 2,710 cells/cc for the initial measurement at hog facility while the cattle barn yielded a reading of 100,000 cells/cc. Both of the bacterial parameters show an unexpected high reading about 6 hours after the initial measurement at the control station (A), as exhibited by a coliform count of 420 cells/cc (Figure 9.16). This can be attributed to another source of animal waste upstream of the study area. Ammonia and phosphorus measurements also show a 4- to 6-hour lag at the control station for high readings, low initial measurements below the hog facility, and the highest values below the cattle barn. Clearly, this study demonstrates the effectiveness of a waste stabilization pond in lowering the discharge of enteric bacteria and nutrients to Old Woman Creek in comparison to direct discharge from a livestock facility.

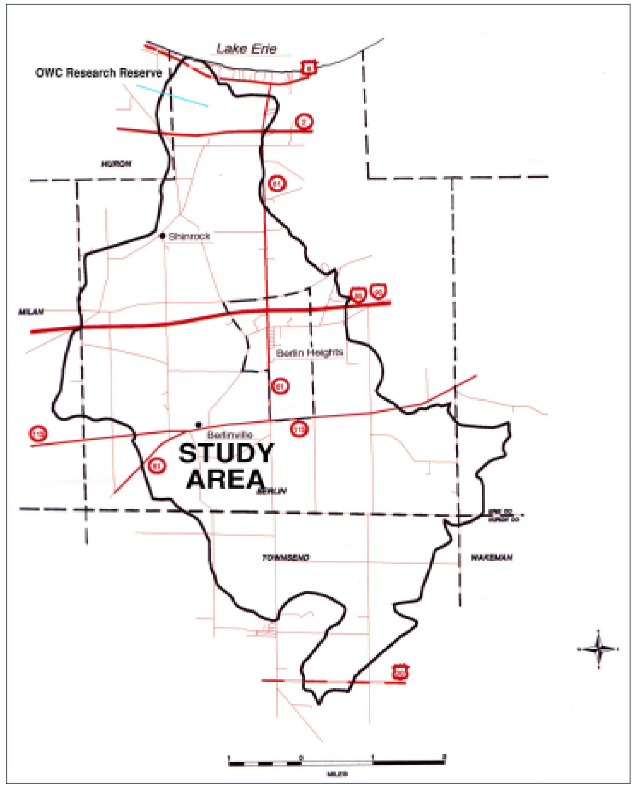


Figure 9.10. Location of livestock waste study area southwest of Berlin Heights, Ohio.

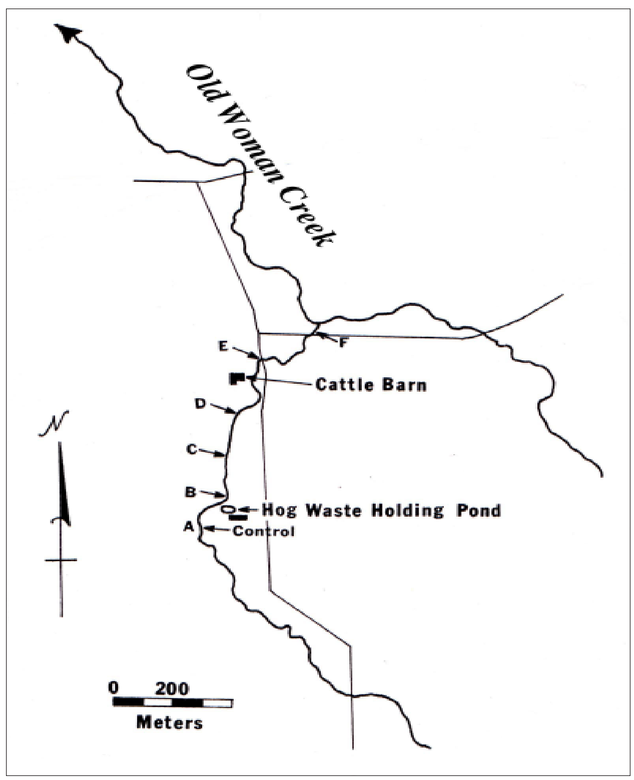


Figure 9.11. Location of water sampling stations. for livestock waste study.

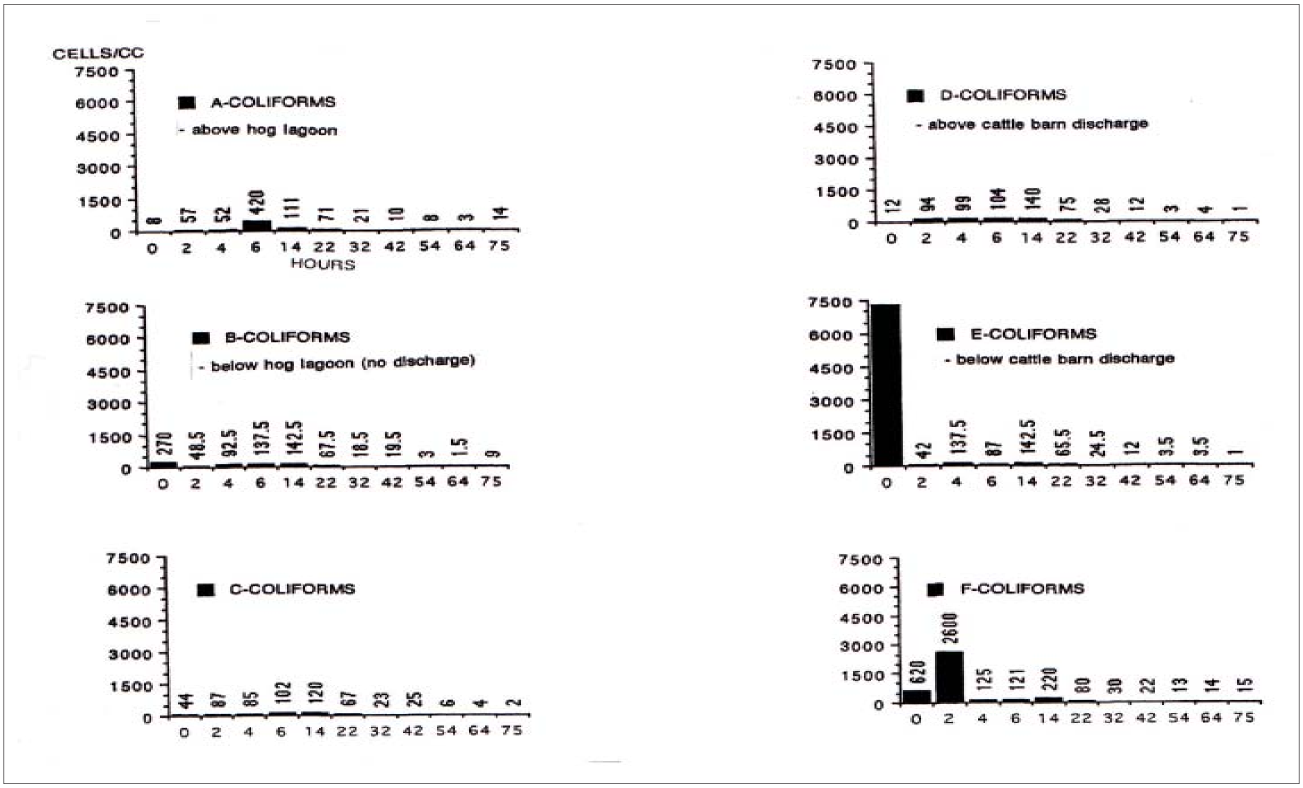


Figure 9.12. Coliform bacteria in Old Woman Creek at livestock waste study area following a rainstorm event in May 1995.

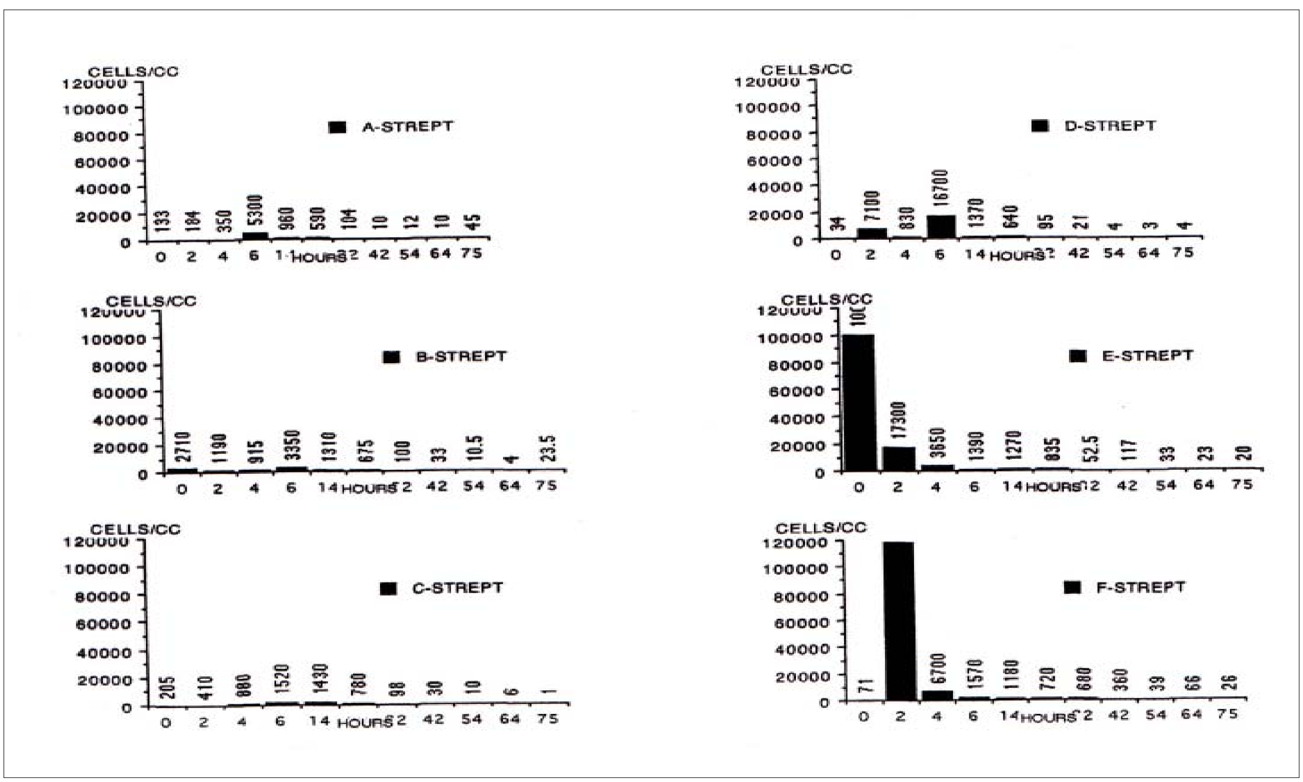


Figure 9.13. Streptococcus bacteria in Old Woman Creek at livestock waste study area following a rainstorm event in May 1995.

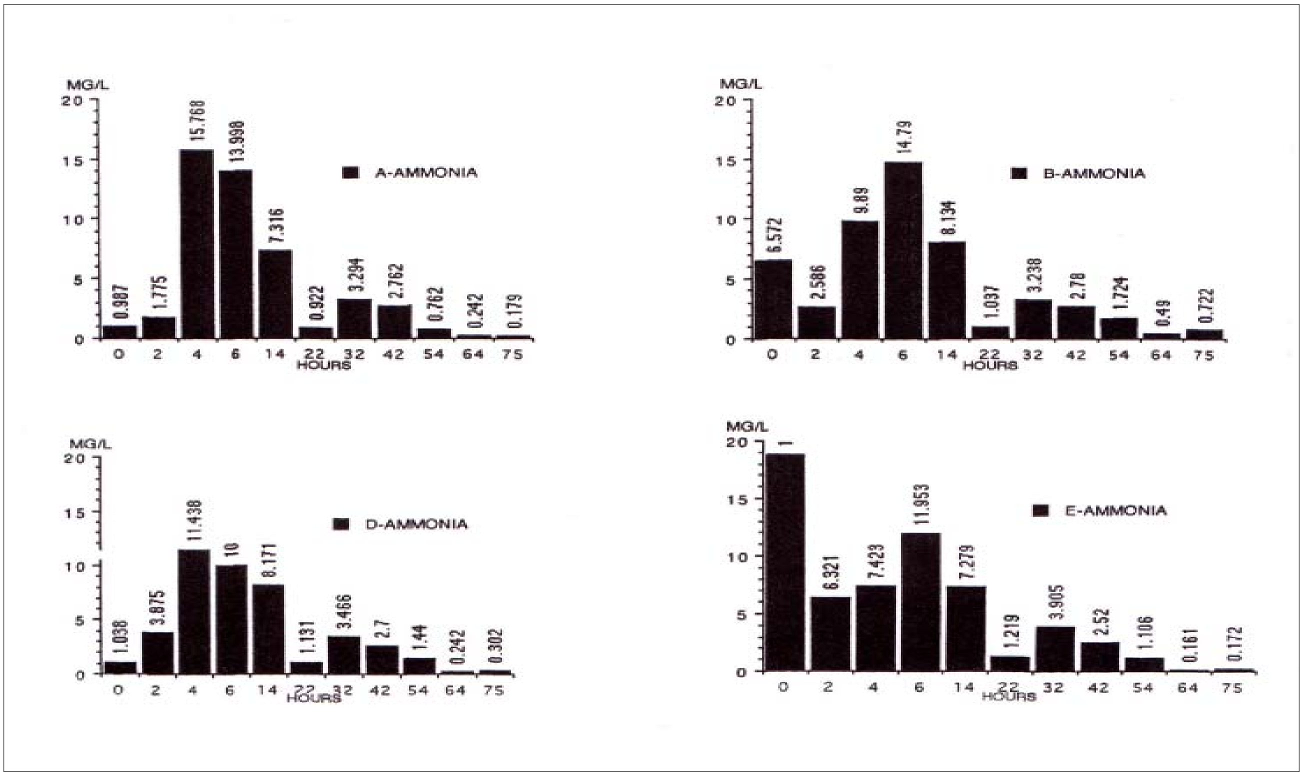


Figure 9.14. Ammonia in Old Woman Creek at livestock waste study area following a rainstorm event in May 1995.

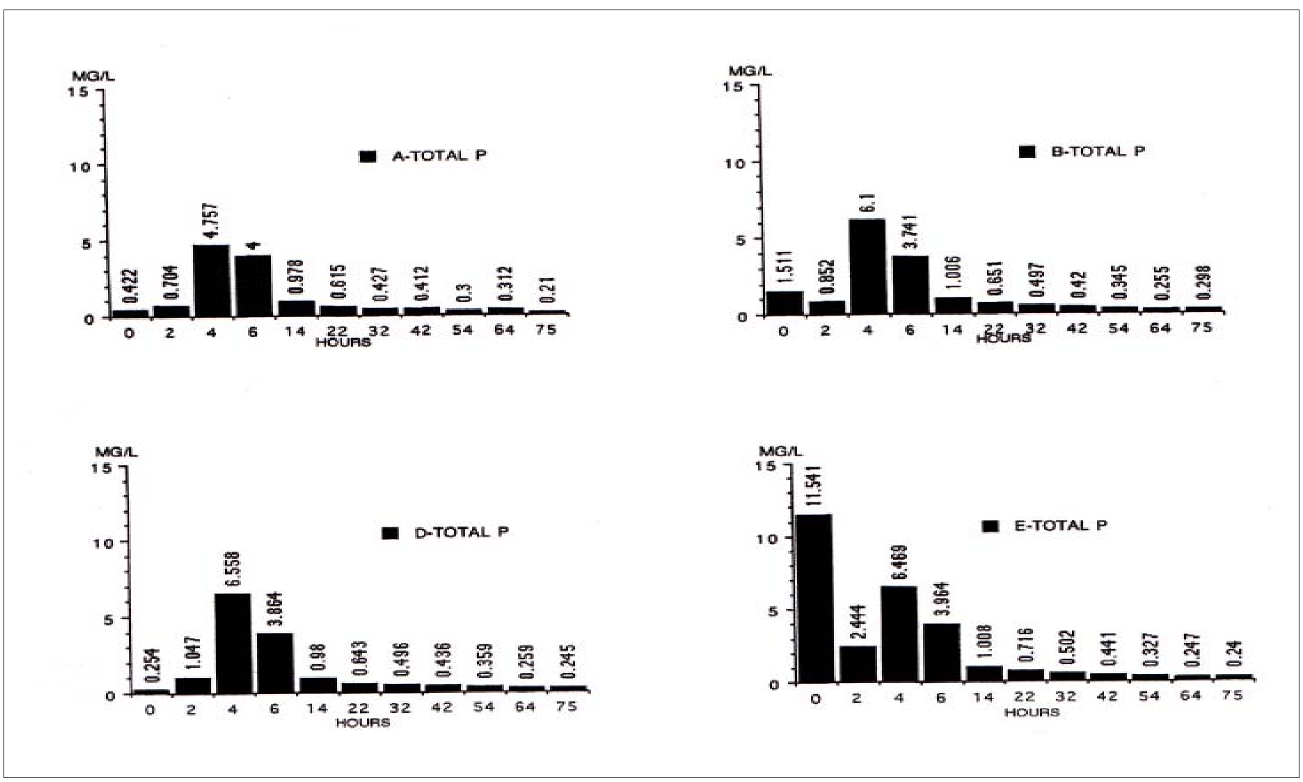


Figure 9.15. Total phosphorus (P) in Old Woman Creek at livestock waste study area following a rainstorm event in May 1995.

PRECISION FARMING

In 1996 and 1997, Old Woman Creek NERR coordinated a demonstrated project dealing with habitat management and non-point pollution reduction within the watershed and to exchange information and technology developed as a result of the project (Wright et al. 1997, 1998, 2000). Specifically, the project focused on precision farming and streambank stabilization within the Old Woman Creek watershed. The goal of the precision farming project was to protect surface and ground waters from pollution caused by excess application of agricultural chemicals. This state-of-the-art technology was made possible via a satellite-linked data sharing system. Participating farmers had each acre of their crop fields tested and soils mapped. The resultant physical and chemical parameters were entered into and analyzed by a computer software program and the outputs were made available to local suppliers of fertilizer, seed, and soil supplements. The result was a customized application plan for each farmer that would reduce pollution to the watershed streams, the estuary, and Lake Erie by using less chemicals on their soils, while achieving economic viability and sustainability.

In February 1999, local farmers who had participated in the project met at the Reserve to share results of their fall harvest yield monitoring efforts and discuss the pros and cons of the computer software, satellite-based technology, and variable applicator equipment. The project successfully demonstrated that non-point pollution reduction through precision farming generated economic benefits for farmers, the environment, and watershed community through improved water quality.

Likewise, streambank stabilization projects within the Old Woman Creek watershed have been effective in improving water quality (Echelberger 1997). In conjunction with the Erie County Water and Soil Conservation District, Old Woman Creek NERR has fostered cooperative program with several watershed farmers to protect stream banks from erosion caused by tillage and livestock facilities that are in close proximity to the water course. By adding greenbelts on the stream banks, re-channeling streams as appropriate, cleaning out ditches, and adding electrified barb wire fences to keep livestock off the stream banks, the banks are healing themselves.

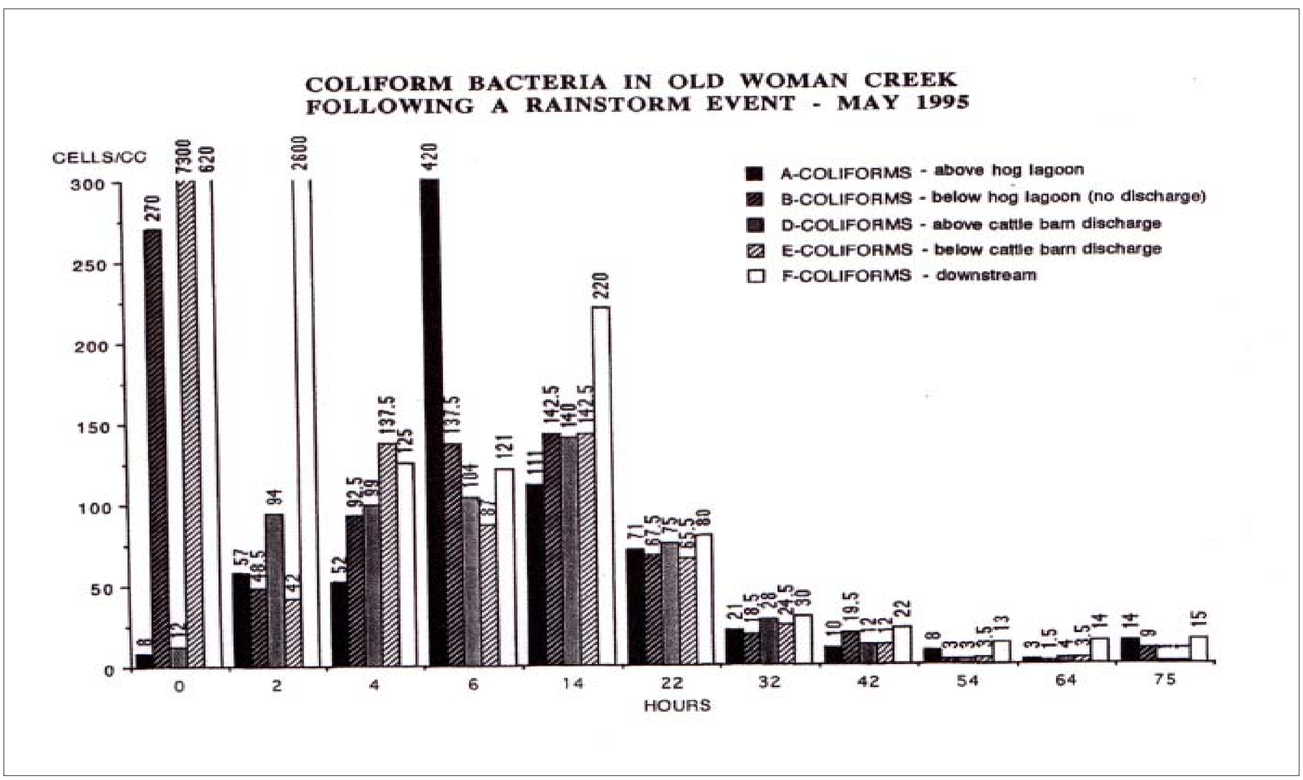


Figure 9.16. Coliform bacteria in Old Woman Creek at livestock waste study area for 72 hours following a rainstorm event in May 1995.

Hazardous Materials

As a precaution to the ever-increasing threat to ecologically sensitive coastal wetlands from catastrophic oil spill and other hazardous material releases (Figure 9.17), the Old Woman Creek NERR undertook an investigation of the potential for such accidents in the Reserve and the surrounding watershed. The result of this effort was the publication of a spill response manual that focused on the land use activities that occur within the Old Woman Creek drainage basin (Wright et. al. 1991). An inventory of potential sources and pathways for spills within the watershed yielded useful land use data. For example, two primary types of spill hazards exist within the watershed: (1) those associated with transportation corridors (Figure 9.18) and (2) those at fixed sites. These corridors or stationary sites either convey or hold hazardous materials, that if spilled within the watershed would ultimately enter the estuary, with the potential to cause severe environmental damage. Transported hazardous materials include: (1) petroleum and associated products, (2) toxic chemicals, (3) radioactive chemicals, and (4) bulk materials (e.g. ice control salts); whereas fixed sites hazardous materials consist of: (1) petroleum and associated products, (2) pesticides and herbicides, (3) liquid fertilizers, (3) industrial and commercial chemicals, (4) bacterial and viral chemicals, and (5) domestic chemicals. Statistically, the watershed contains the transportation corridors and fixed sites given in Table 9.7.

In addition to potential for spills of hazardous materials within the watershed, Old Woman Creek estuary is also vulnerable to spill which may occur in the adjacent portions of Lake Erie. Short term oscillations in Lake Erie water level, (e.g. seiches and wind tides induced by certain wind or barometric conditions) periodically cause lake water to enter the estuary from the open lake. Such oscillations between one high level and the subsequent high level have periods of generally 12 to 14 hours. Therefore, if a spill was to occur in the nearshore waters of the lake, response actions would need to be taken to potect the estuary from lake water, as well as the lake beaches.

Figure 9.17. Hazardous materials warning placards.

TABLE 9.7. TRANSPORTATION CORRIDORS AND FIXED SITES IN THE WATERSHED

Highway & Railroad	**miles**
4–lane highways (Ohio Tpk & Rt. 2)	9
2–lane highways (primary roads)	21
2–lane highways (secondary roads)	82
railroad tracks	8
	no.
4–lane x 2–lane intersections	2
2–lane x 2–lane intersections (primary)	63
4–lane x 2–lane intersections (secondary)	73
railroad x highway intersections	7
bridges & overpasses	8
Pipelines and Transmission Lines	**miles**
pipelines (petroleum & associated products)	9
pipelines (natural gas)	14
transmission lines (high voltage)	27
Buildings	**no.**
houses (total in 1991)	1,646
houses (new between 1979 & 1991)	284
barns, greenhouses, & outbuildings	452
commercial buildings	58
public & community buildings	14
industrial buildings	9
storage facilities (oil, gas, & chemicals)	11

Recent Land Cover Changes

As this Site Profile was about to go to press, new watershed land cover maps became available for the mid-1990s and 2003 (Figures 9.19 and 9.20). These maps show very little change in land cover over the past decade, illustrating that recent development has been very slow within the watershed.

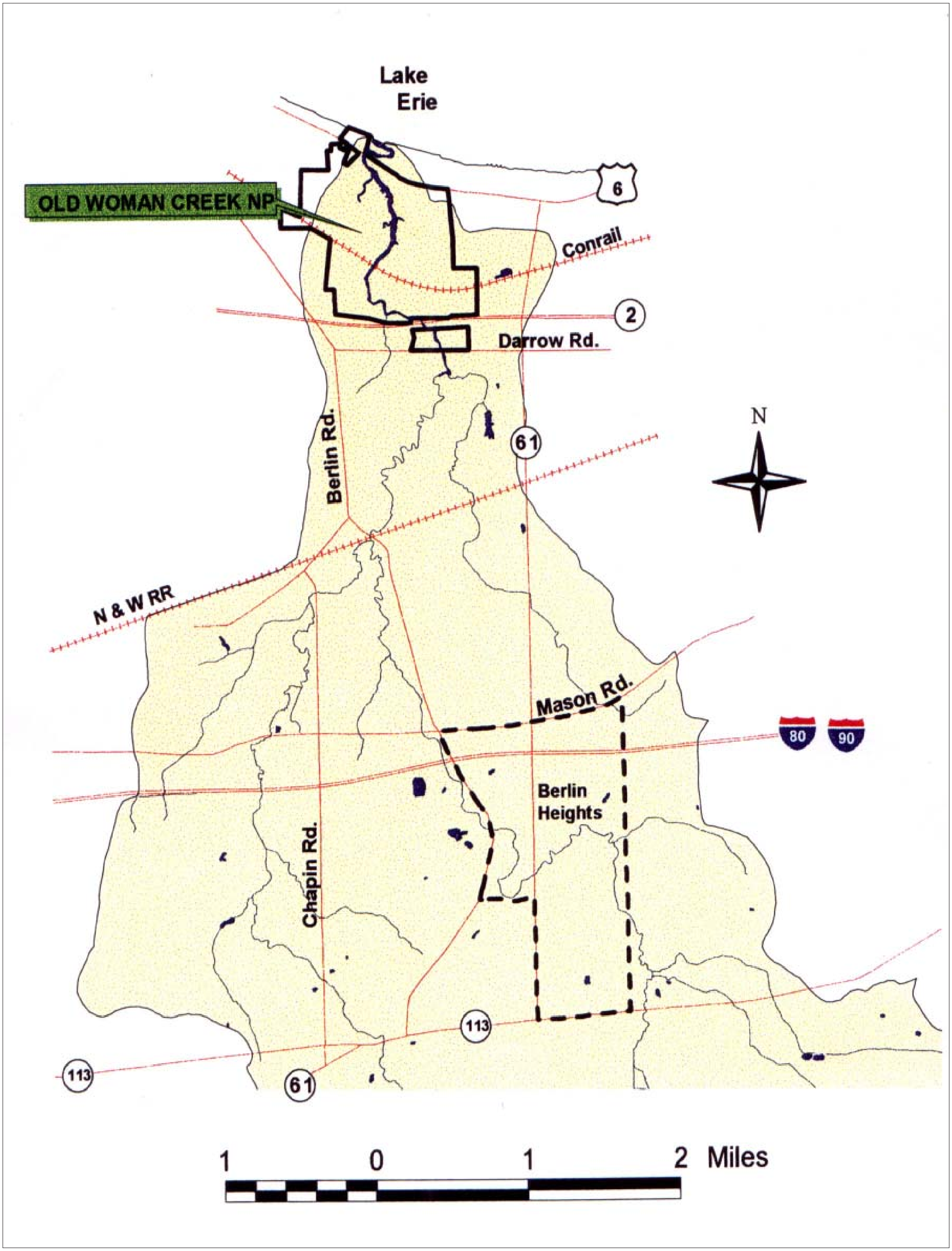


Figure 9.18. Transportation corridors in the lower Old Woman Creek watershed.

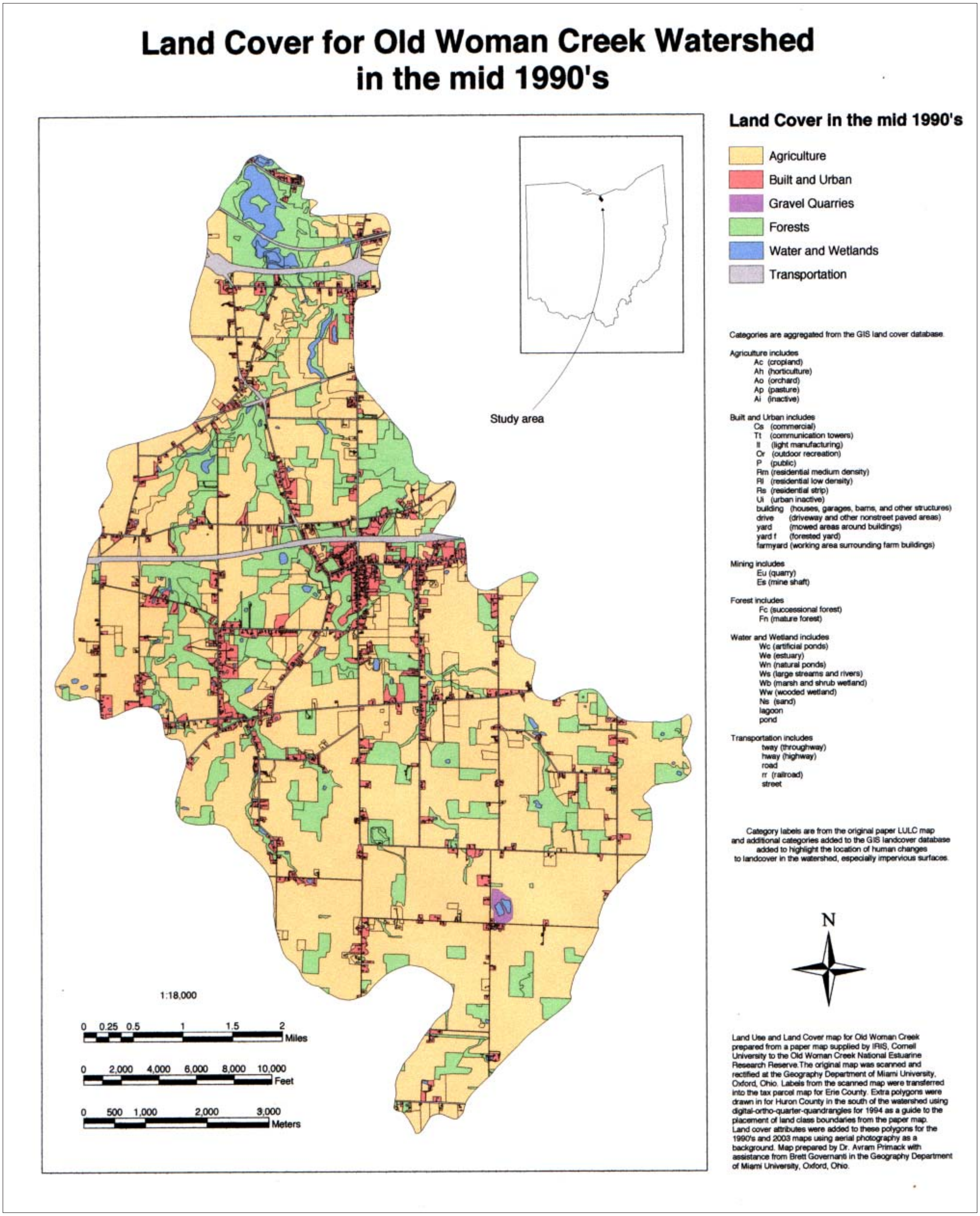


Figure 9.19. Old Woman Creek watershed land cover in the mid-1990s (Primack and Governanti 2004).

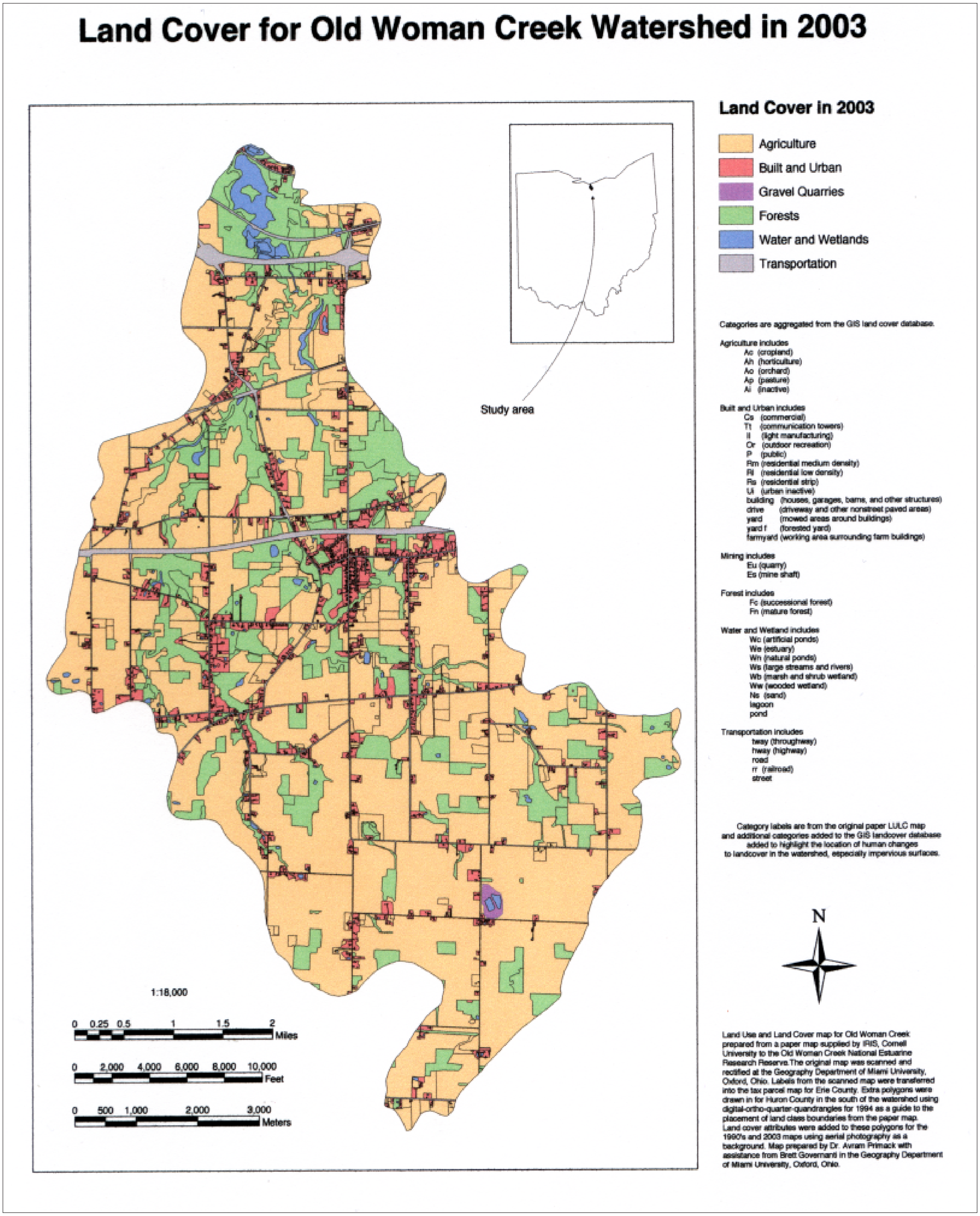


Figure 9.20. Old Woman Creek watershed land cover in 2003 (Primack and Governanti 2004).

Aerial view of Old Woman Creek estuary showing land utilization (NOAA/NOS/National Geodetic Survey, June 1997).

Chapter 10. Conclusions

Synopsis

The Coastal Zone Management Act of 1972, as amended, established a system of National Estuarine Research Reserves (NERR) which are funded cooperatively by the National Oceanic and Atmospheric Administration (NOAA), Office of Ocean and Coastal Resource Management and the host States or Territories, and managed by the States or Territories. The NERR System (NERRS) has two missions: (1) to establish and maintain, through Federal-State cooperation, a national system of Estuarine Reserves that are representative of various biogeographic regions in the U.S. and (2) to conduct long-term research, educational, and interpretive activities in support of national coastal zone management priorities.

NERRS sites have been selected to represent the range of biogeographic regions and estuarine types occurring throughout the United States. To date, NOAA has designated 27 National Estuarine Research Reserves which collectively comprise 1,137,833 acres of estuaries and their associated terrestrial habitats (Figure 10.1). Two additional sites are in the designation process.

The Old Woman Creek National Estuarine Research Reserve (OWC NERR) was officially designated by NOAA in 1980. The Reserve is administered by the Division of Wildlife within the Ohio Department of Natural Resources. OWC NERR is the smallest Reserve in the national system, comprising 571 acres of protected lands and water along the southwestern shore of Lake Erie. Facilities at this site include a visitor center, trail network, research laboratories, teaching rooms, reference library, dormitories, boat house, and maintenance/storage buildings (Figure 10.2).

The OWC NERR represents the only Great Lakes estuary within the NERR System. Several important estuarine, lacustrine, and terrestrial habitats are located within the Reserve. These include open estuarine waters, remnant embayment marshes, mudflats, oak-

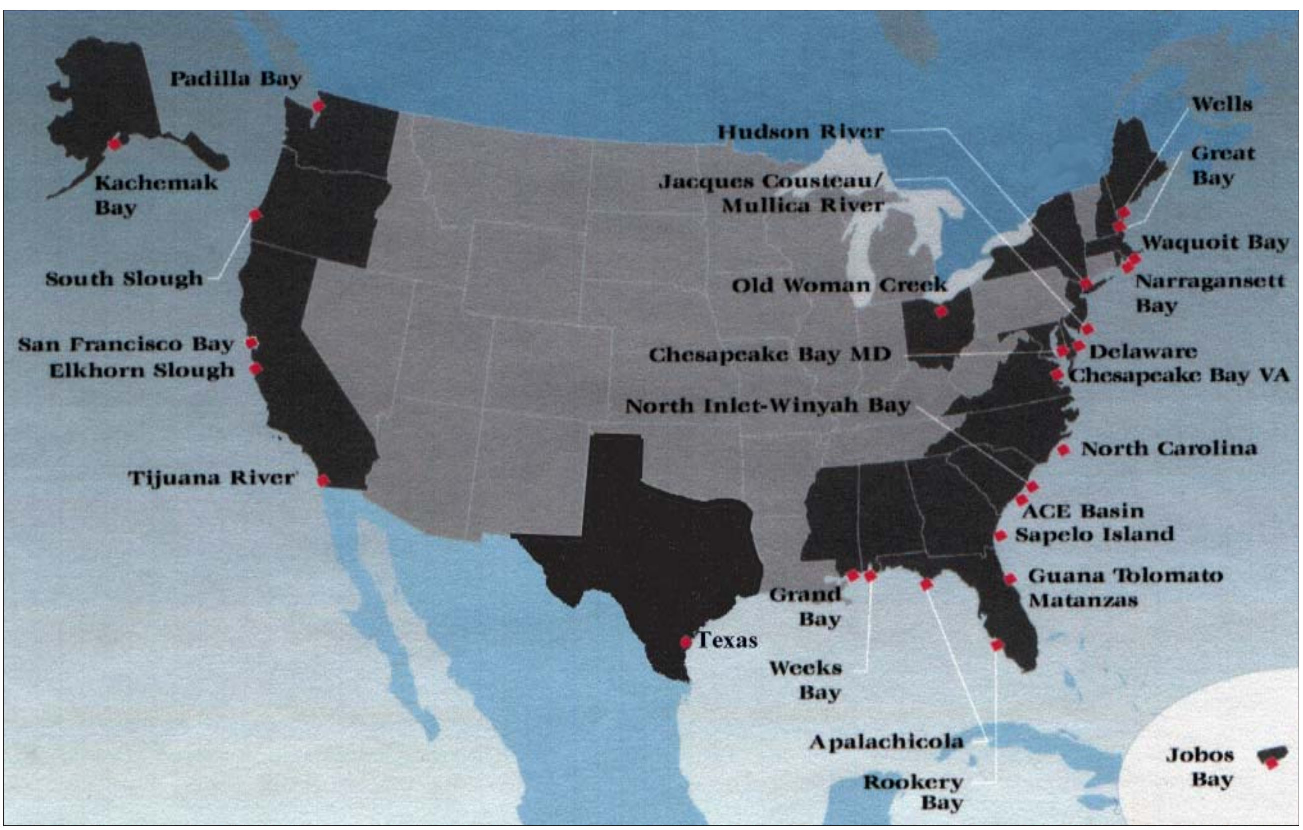


Figure 10.1. United States National Estuarine Research Reserve System (NOAA).

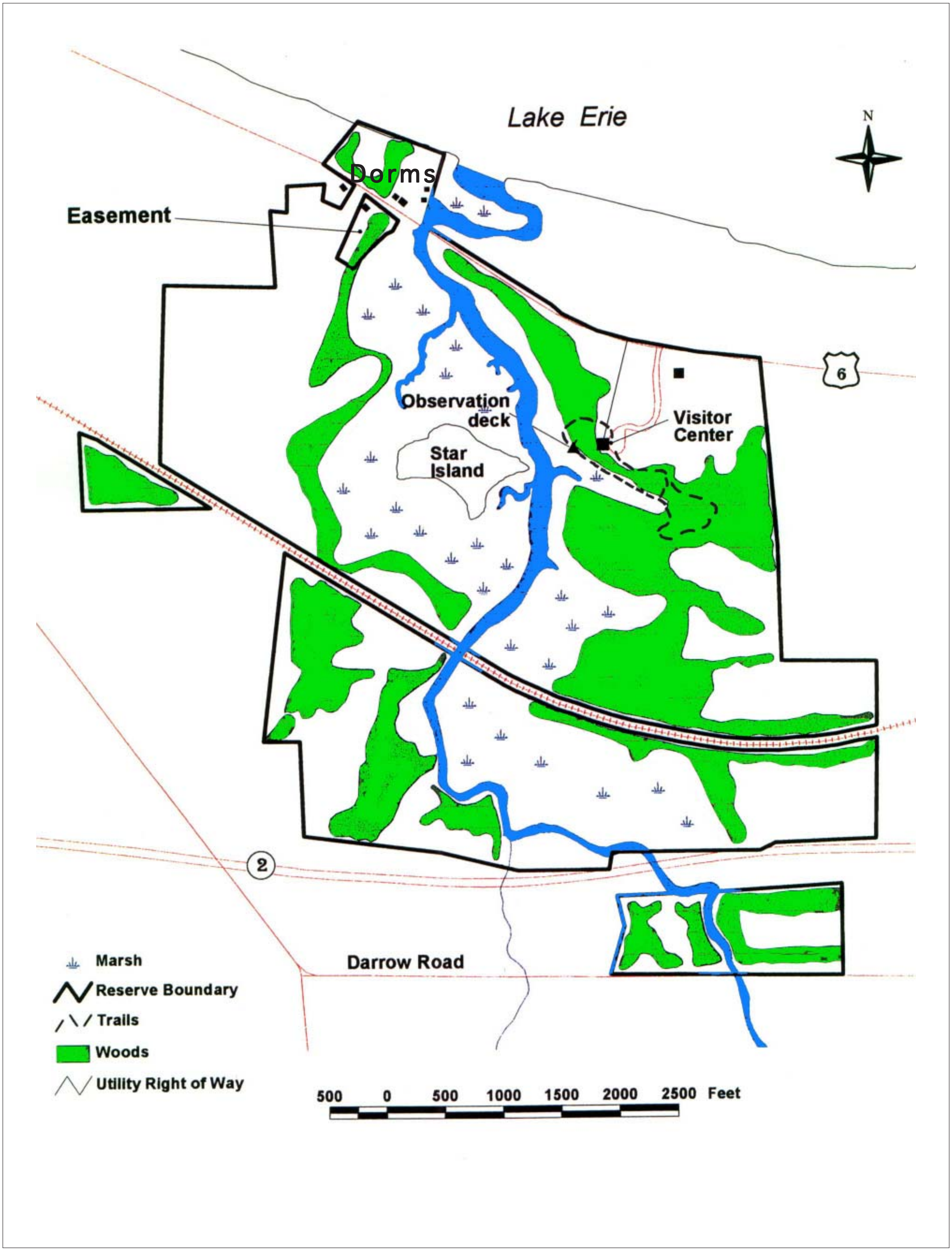


Figure 10.2. Old Woman Creek State Nature Preserve and National Estuarine Research Reserve.

hickory upland hardwood forests, a swamp forest, a sandy barrier beach, and the waters of Lake Erie (Figure 10.3).

The advance and retreat of the glaciers and the resulting glacial lakes during the Wisconsinan Period were instrumental in determining the soils and land form of the Old Woman Creek (OWC) watershed. In the nineteenth century, the virgin forests in the watershed were harvested, land was cleared, and farms were established. Today, agricultural pursuits account for approximately 65% of land use in the watershed. The high proportion of agriculture over the past 150 or so years has resulted in an estuary that is nutrient rich. Despite this overabundance of nutrients, the estuary still traps or transforms the majority of phosphorus and nitrogen pollutants that enter.

Within the boundaries of the OWC Reserve, a diverse assemblage of plants and animals reside. This assemblage is representative of the terrestrial and coastal wetland habitats that were once prominent in the lower Great Lakes. Table 10.1 provides an inventory of the natural features and resources that have been documented for this area.

The goal of the OWC NERR research program is to develop a better understanding of the freshwater estuarine system. The objective of studies undertaken in OWC is to determine the role of freshwater estuaries and other coastal wetland areas in the Great Lakes ecosystem. Results from these studies provide useful information to coastal zone managers and decision-makers in the Lake Erie area and the Great Lakes region.

Research conducted at OWC NERR to date has demonstrated that the estuary is a very dynamic system which is constantly changing. Two separate processes—changing Lake Erie water levels and storms—largely control these changes in the estuary.

CHANGING LAKE LEVELS

Unlike traditional marine estuaries where water level changes are generally predictable, water levels in the five Great Lakes are erratic and fluctuate not only daily, but also seasonally and annually. Changes in Lake Erie water levels are mirrored in the Old Woman Creek estuary. The impact of seasonal and annual changes in Lake Erie water level on the aquatic

Figure 10.3. Bird's-eye view of Old Woman Creek estuary (Linda Feix).

TABLE 10.1. INVENTORY OF NATURAL FEATURES AND RESOURCES WITHIN OLD WOMAN CREEK WATERSHED AND ADJOINING LAKE ERIE

GEOLOGY	
Bedrock Formations	**Age (YBP)[1]**
Ohio Shale (Devonian)	370 million
Bedford Shale (Mississippian)	360 million
Berea Sandstone (Mississippian)	350 million
Glacial Deposits	
Wisconsinan Ground Moraine (Till)	15,000–25,000
Wisconsinan Outwash Deposits	15,000–18,000
Glacial Lakes Sediments, Deltas, & Beach Ridges	
Glacial Lake Maumee (elevation 800 ft)	14,440–13,800
Glacial Lake Arkona (elevation 700 ft)	13,800–13,660
Lake Ypsilanti–low stage (elevation 260 ft)	13,600–13,000
Glacial Lake Whittlesey (elevation 740 ft)	13,000–12,800
Glacial Lakes Warren (elevation 680 ft)	12,800–12,700
Glacial Lake Wayne (elevation 660 ft)	12,700–12,600
Glacial Lake Grassmere (elevation 640 ft)	12,600–12,500
Glacial Lake Lundy (elevation 620 ft)	12,500–12,400
Post-Glacial Deposits	
Lacustrine (Lake) Sediments	
Early Lake Erie (elevation 490 ft)	12,400–8,000
Middle Lake Erie (elevation 525 ft)	8,000–4,000
Modern Lake Erie (elevation 570 ft)	4,000–present
Estuary Sediments & Wetland Deposits	4,000–present
Floodplain Alluvium	4,000–present
Modern Soils	**Soil types (no.)**
Bedrock Parent Materials	3
Glacial Till Parent Materials	14
Glacial Outwash Parent Materials	12
Ancient Beach Ridge Parent Materials	8
Lacustrine Deposits Parent Materials	23
Delta Deposits Parent Materials	3
Floodplain Alluvium Parent Materials	3

[1] YBP—years before the present

TABLE 10.1. INVENTORY OF NATURAL FEATURES AND RESOURCES WITHIN OLD WOMAN CREEK WATERSHED AND ADJOINING LAKE ERIE (cont'd)

CLIMATOLOGY

Average Weather Conditions

Sunny Days:

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
32	49	59	36

Rainy Days:

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
16	20	15	14

Thunderstorm Days:

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1	14	15	1

Snowy Days (> 1 inch):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
7	0	0	3

Hot Days (> 90°F):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
0	11	8	0

Cold Days (< 32°F):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
70	10	0	42

Average Air Temperature

Minimum Daily (°F):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
24°	51°	62°	36°

Maximum Daily (°F):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
38°	69°	80°	51°

Average Lake Temperature (°F):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
35°	55°	72°	46°

Total Precipitation

Rainfall Equivalent (inches):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
7.4	10.7	9.6	6.3

Snowfall (inches):

Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
19.1	1.1	0.0	8.6

TABLE 10.1. INVENTORY OF NATURAL FEATURES AND RESOURCES WITHIN OLD WOMAN CREEK WATERSHED AND ADJOINING LAKE ERIE (cont'd)

HYDROLOGY

Drainage Basin
- Watershed (Surface Drainsge Basin) Area: 27 sq miles
- Groundwatershed (Subsurface Drainage) Area: 900 sq miles
- Ponds (Total No.: 45) Surface Area: 2.3 million sq ft

Estuary (Average for Summer 1998)
- Area: 5.7 million sq ft; Volume: 10.5 million cu ft; Depth: 1.8 ft

Old Woman Creek (Total Stream Length: 46.6 miles)
- West Branch
  - 1st Order Tributaries (No.: 13; Total Length: 6.8 miles)
  - 2nd Order Tributaries (No.: 3; Total Length: 7.1 miles)
  - 3rd Order Tributaries (No.: 1; Total Length: 1.2 miles)
- East Branch
  - 1st Order Tributaries (No.: 11; Total Length: 17.5 miles)
  - 2nd Order Tributaries (No.: 3; Total Length: 4.2 miles)
  - 3rd Order Tributaries (No.: 1; Total Length: 4.7 miles)
- Main Stem & Estuary
  - 1st Order Tributaries (No.: 4; Total Length: 1.8 miles)
  - 4th Order Tributaries (No.: 1; Total Length: 3.3 miles)

Lake Erie
- Water Levels (above Atlantic Ocean, IGLD 1985)
  - Low Water Datum: 569.2 ft
  - Mean Lake Level: 571.3 ft
  - Average Lake Level for 1998 Summer: 573.2 ft
  - Flooding Potential at Estuary Mouth
    - Once Every 10 Years: 574.9 ft
    - Once Every 50 Years: 575.8 ft
    - Once Every 100 Years: 576.0 ft; 500 Years: 576.6 ft
- Extreme Offshore Lake Waves (height above still water level)
  - Northwest Storms
    - Once Every 10 Years: 7.9 ft
    - Once Every 50 Years: 10.8 ft
    - Once Every 100 Years: 12.7 ft
  - Northeast Storms
    - Once Every 10 Years: 9.5 ft
    - Once Every 50 Years: 14.1 ft
    - Once Every 100 Years: 15.7 ft

TABLE 10.1. INVENTORY OF NATURAL FEATURES AND RESOURCES WITHIN OLD WOMAN CREEK WATERSHED AND ADJOINING LAKE ERIE (cont'd)

BOTANY

- Plant Species: 2,169 species
  - Algae: 682 species
    - Kingdom Monera – 49 species
      - Cyanobacteria (blue-green algae) – 49 species
    - Kingdom Protista (plant-like) – 633 species
      - Rhodophytes (red algae) – 1 species
      - Chrysophytes (golden & yellow-green algae) – 351 species
        - Chrysophyceae (golden-brown algae) – 32 species
        - Xanthophyceae (yellow-green algae) – 6 species
        - Bacillariophyceae (diatoms) – 313 species
      - Pyrrhophytes (fire algae) – 10 species
      - Cryptophytes (crytomonads) – 21 species
      - Euglenophytes (euglenoids) – 77 species
      - Chlorophytes (green algae) – 173 species
  - Fungi: 472 species
    - Kingdom Fungi – 472 species
      - Myxomycetes (slime molds) – 50 species
      - Phycomycetes (algal fungi & water molds) – 61 species
      - Ascomysetes (yeasts, molds & cup fungi) – 52 species
      - Basidiomycetes (mushrooms & rusts) – 147 species
      - Deuteromycetes (imperfect fungi) – 51 species
      - Mycophycohytes (lichens) – 111 species
  - Vascular Plants (estuarine and upland): 1,015 species
    - Kingdom Plantae – 1,015 species
      - Bryophytes (mosses & liverworts) – 156 species
      - Lycopodiophytes (clubmosses) – 2 species
      - Equisetophytes (horsetails) – 2 species
      - Filicophytes (ferns) – 18 species
      - Pinophytes (gymnosperms/conifers) – 8 species
      - Magnoliophytes (angiosperm/flowering plants) – 829 species

TABLE 10.1. INVENTORY OF NATURAL FEATURES AND RESOURCES WITHIN OLD WOMAN CREEK WATERSHED AND ADJOINING LAKE ERIE (cont'd)

ZOOLOGY

- Animal Species: 1,968 species
  - Kingdom Protista (animal-like): 318 species
    - Protozoans – 318 species
      - Sarcomastigophora - 198 species
      - Ciliophora - 120 species
  - Kingdom Animalia: 1,650 species
    - Invertebrates: 1,055 species
      - Poriferans (sponges) – 2 species
      - Cnidarians (hydrozoans) – 2 species
      - Turbellarians (flatworms) – 5 species
      - Annelids (segmented worms & leeches) – 46 species
      - Rotifers – 34 species
      - Nematodes (roundworms) – 3 species
      - Gastrotichs – 2 species
      - Mollusks (clams & snails) – 33 species
      - Tardigrades (water bears) – 1 species
      - Bryozoans (moss animals) – 5 species
      - Arthropods: 922 species
        - Arachnida (spiders & water mites) – 77 species
        - Crustaceans – 87 species
        - Insects – 758 species
    - Vertebrates: 595 species
      - Fishes: 121 species
        - Jawless Fishes (lampreys) – 2 species
        - Bony Fishes – 119 species
      - Amphibians: 27 species
        - Salamanders – 16 species
        - Frogs & Toads – 11 species
      - Reptiles: 25 species
        - Turtles – 8 species
        - Snakes – 17 species
      - Birds: 370 species
      - Mammals: 51 species
        - Marsupials (opossums) – 1 species
        - Insectivores (moles & shrews) – 5 species
        - Bats – 8 species
        - Carnivores – 9 species
        - Rabbits – 1 species
        - Rodents (squirrels, muskrats & mice) – 14 species
        - Ungulates (deer & bison) – 2 species
        - Primates (man) – 1 species

vegetation in the estuary can be both rapid and dramatic. During the period of high Lake Erie water levels (1980-1999) *Nelumbo lutea* (American water lotus) was the dominant plant in the estuary, often covering up to 35% of the estuary with the remaining area being open water (see Figures 7.11 and 7.12). Emergent vegetation was confined to a very narrow band along the shoreline of the estuary. When Lake Erie water levels dropped in 1999, more than half of the open water areas, previously under water, became exposed during the following spring. These exposed areas were quickly colonized by emergent vegetation. In 2000, more than 50% of the estuary was dominated by emergent plants, while open water areas had diminished from greater than 65% to less than 35% of the estuary. Based on our work at OWC, and from earlier studies, the changes in vegetation caused by changes in water level are cyclical. When high lake levels return, conditions in the estuary are expected to revert to those conditions observed from 1980 to 1999.

STORM EVENTS

Storm events have a major impact on water quality and quantity in OWC estuary as well as on the biota inhabiting the estuary. Strong wind events and resulting seiches can drive lake water up into the estuary or can drain the estuary. Wind activity on the lake over time will deposit sand in the estuary mouth and close the barrier beach isolating the estuary from the lake proper.

Rain storms in the watershed result in storm waters flowing into the estuary. If the mouth is closed, it is stormwater that will breach the barrier beach and re-connect the estuary with the lake. These stormwaters can be turbid and laden with excess nutrients and other pollutants. As these waters pass through the estuary many of these pollutants are either trapped or transformed.

The biotic populations, particularly planktonic communities, are strongly impacted by storm events. An influx of lake water brings lake populations into the estuary. Stormwater inflow from the watershed can result in the estuarine plankton populations being washed out into Lake Erie. These inflows can act as a two-edged sword. On one hand, they flush out the bulk of the existing estuarine populations; on the other hand, they bring into the estuary nutrients that are necessary for rapid re-colonization.

When the mouth is open the populations in the estuary are regulated primarily by physical factors, particularly water level and water flow. However, when the mouth is closed, biological interactions such as competition and predation become much more important.

FUTURE RESEARCH INITIATIVES

Since 1980, the OWC research program has focused on descriptions of biological communities in the estuary and of major processes that impact the estuary. In compiling this document we have synthesized our understanding of a freshwater estuary and noted areas where critical information is missing in that understanding of OWC in the Lake Erie ecosystem and the ecology of the estuary and its watershed. Five areas for potential research are identified below.

MACROPHYTE DETRITUS

The recent decline in Lake Erie water levels has had major ramifications in the ecology of the estuary. The impact of these changes on the estuary and the nearshore zone of Lake Erie should be studied. An obvious result of declining water levels in the estuary has been the proliferation of aquatic macrophytes (Trexel-Kroll 2002). Work by Francko and Whyte (1995) suggested that macrophyte production now dominates the carbon production in the estuary. Therefore, studies on: (1) the significance and fate of macrophyte detritus and (2) the resulting breakdown processes with the estuary should be addressed.

ORGANIC CONTAMINANTS

Organic pollution of the Great Lakes became a concern in the past decade and has every indication of remaining a major problem for the foreseeable future. Studies by Chin et al. (1998), Everett et al. (1999), and Miller and Chin (2002) have demonstrated the role that wetland areas along the Great Lakes may play in mitigating this pollution. Their work should be expanded to provide information to coastal managers on the impact and fate of organic contaminants in coastal wetlands and the receiving Great Lakes.

BACTERIAL COMMUNITIES

The impact of bacterial communities—and the food webs that develop around these microorganisms—has received little attention. However, research by Lavrentyev et al. (1998) has reinforced the importance of bacteria to food webs and chemical cycling in the estuary.

LAND USE

The impact of major changes in land use activities in the watershed should be further investigated and a planning model developed as an aid in identifying possible management concerns. Different land use activities result in different stresses on the creek and the estuary.

With the completion of a major highway corridor and the initiation of plans for the installation of water lines in the watershed, the potential for low-scale urban development has become both real and immediate. The potential effects of these changing land use patterns on the creek and the estuary make this one of our top research priorities.

GROUNDWATER

Past studies on physical and chemical parameters have provided an understanding of surface water quality; however, relatively little is known of groundwater abundance, quality, and pathways. Studies such as Matisoff and Eaker (1992) suggest that groundwater may be a minor component in the estuarine hydrologic budget. Although a minor component in the estuary, this may not be the case in the watershed, where many home sites still depend upon water wells for their water. Therefore, a study of groundwater quantity and quality would be critical to good management planning, particularly in light of the potential for increased urbanization within the watershed.

As these research objectives are addressed and results forthcoming, compelling educational programs should be developed to communicate this information to students, citizens, and coastal managers (Figures 10.4 and 10.5). Out of this information transfer and a broadening understanding of the role of estuaries and other coastal wetlands in the Great Lakes ecosystem, enlightened management initiatives will likely develop.

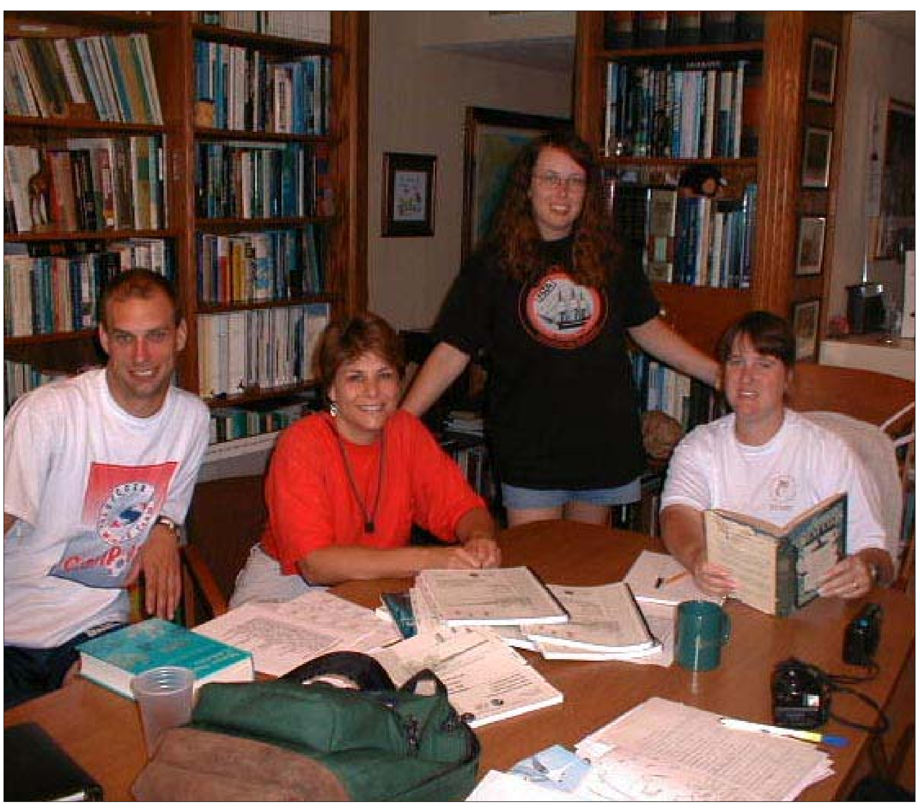


Figure 10.4. Teacher training workshop focused on the value of coastal wetlands (Charles E. Herdendorf).

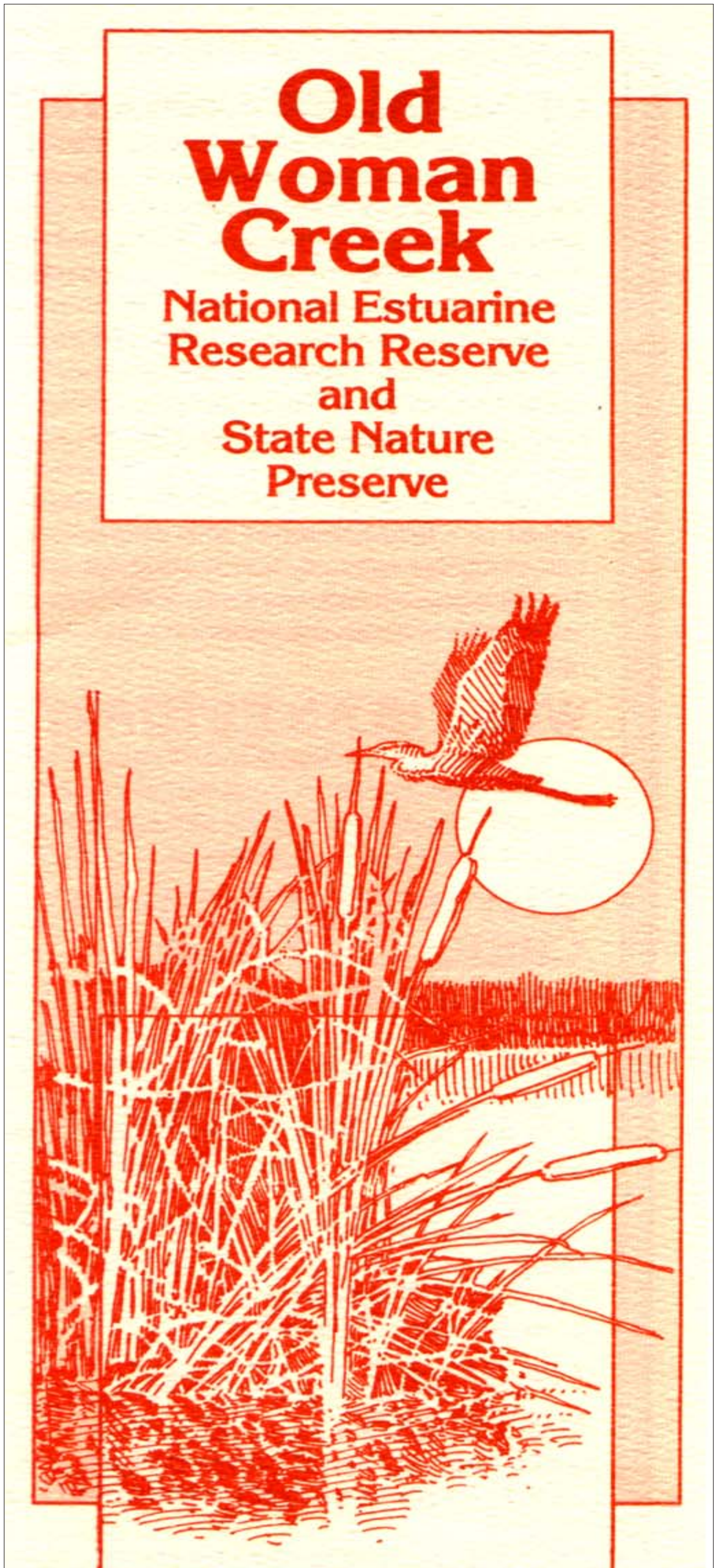
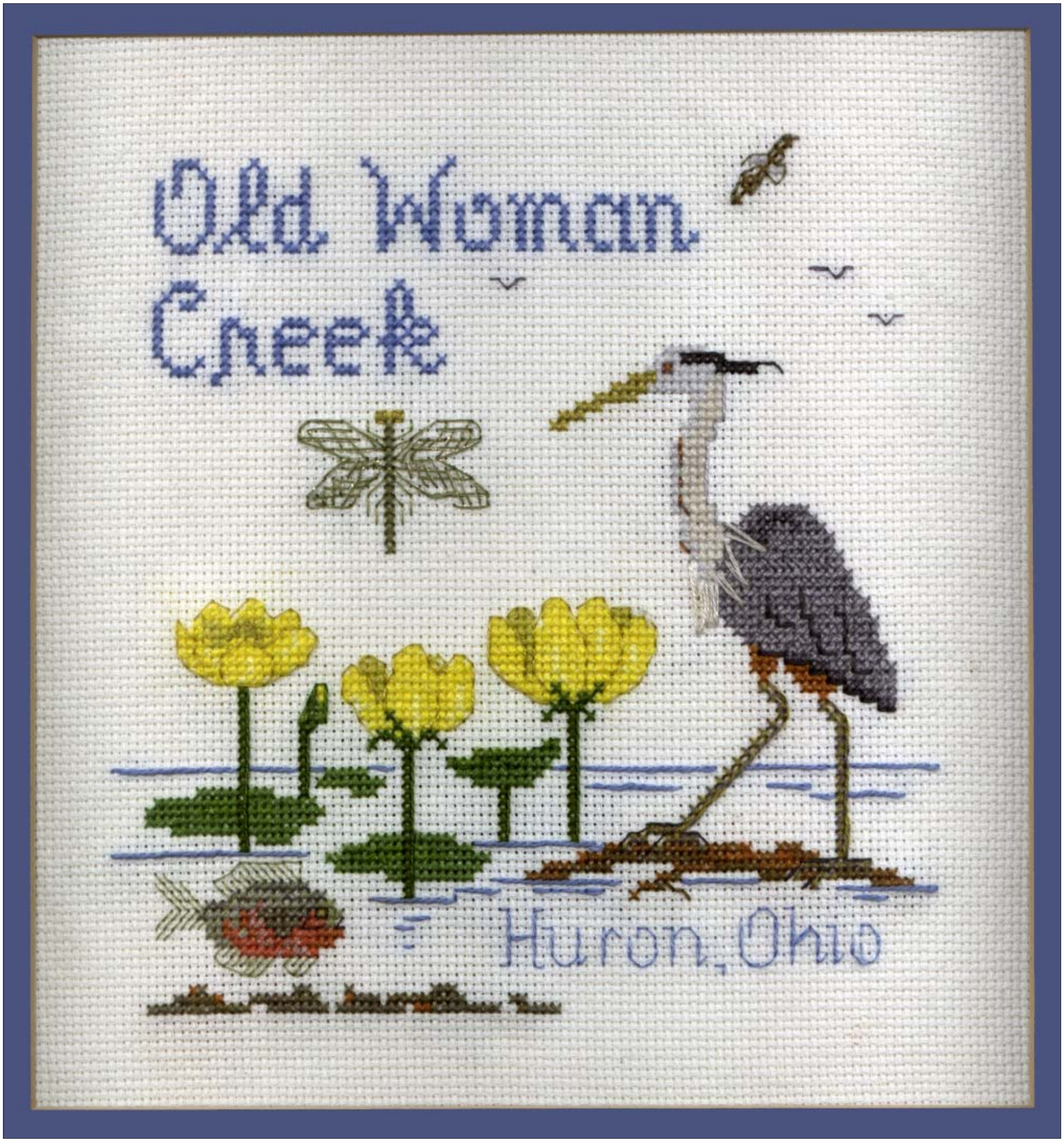


Figure 10.5. Old Woman Creek National Estuarine Research Reserve and State Nature Preserve brochure (ODNR).



Cross-Stitch of Old Woman Creek (Friends of Old Woman Creek, Inc.).

11. Acknowledgments

When beginning this Site Profile, the authors proposed to create a document that was both readable by the layman and usable by the scientist. How well we succeeded in this goal can only be determined by the reader.

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12. Appendixes

APPENDIX A. ALGAL FLORA AND LOWER PLANTS OF OLD WOMAN CREEK ESTUARY, WATERSHED, AND ADJACENT WATERS OF LAKE ERIE

KINGDOM MONERA

DIVISION CYANOPHYTA (blue-green algae)
CLASS CYANOPHYCEAE

Order Chroococcales	**Common Name**	**Family**	**Location**
Aphanocapsa delicatissima	blue-green	Chroococcaceae	ES
Aphanocapsa elachista	blue-green	Chroococcaceae	ES
Aphanocapsa incerta	blue-green	Chroococcaceae	CK
Aphanothece saxicola	blue-green	Chroococcaceae	ES
Chroococcus dispersus	blue-green	Chroococcaceae	CK,ES
Chroococcus minor	blue-green	Chroococcaceae	CK
Chroococcus minutus	blue-green	Chroococcaceae	CK,LE
Chroococcus planctonicus	blue-green	Chroococcaceae	ES
Chroococcus spp.	blue-greens	Chroococcaceae	CK,ES
Coelosphaerium naegelianum	blue-green	Chroococcaceae	ES
Coelosphaerium pallidum	blue-green	Chroococcaceae	ES
Dactylococcopsis irregularis	blue-green	Chroococcaceae	ES
Gloeocapsa aeruginosa	blue-green	Chroococcaceae	CK
Gloeocapsa sp.	blue-green	Chroococcaceae	ES
Gomphosphaeria lacustris	blue-green	Chroococcaceae	ES
Merismopedia glauca	blue-green	Chroococcaceae	ES
Merismopedia minima	blue-green	Chroococcaceae	CK,ES
Merismopedia tenuissima	blue-green	Chroococcaceae	ES
Microcystis aeruginosa	blue-green	Chroococcaceae	ES
Microcystis minutissima	blue-green	Chroococcaceae	ES
Microcystis sp.	blue-green	Chroococcaceae	ES
Rhabdoderma minima	blue-green	Chroococcaceae	ES
Rhabdoderma sp.	blue-green	Chroococcaceae	ES
Synechococcus leopoliensis	blue-green	Chroococcaceae	ES
Synechococcus sp.	blue-green	Chroococcaceae	ES
Order Oscillatoriales			
Anabaena circinalis	blue-green	Nostocaceae	ES
Anabaena spiroides	blue-green	Nostocaceae	LE
Anabaena spiroides var. *crassa*	blue-green	Nostocaceae	LE
Anabaena variabilis	blue-green	Nostocaceae	ES
Anabaena spp.	blue-greens	Nostocaceae	ES,LE
Aphanizomenon flos-aquae	blue-green	Nostocaceae	ES,LE
Calothrix fusca	blue-green	Rivulariaceae	CK
Calothrix spp.	blue-greens	Rivulariaceae	CK
Lyngba sp.	blue-green	Oscillatoriaceae	CK,ES
Microcoleus lyngbyaceus	blue-green	Oscillatoriaceae	CK
Oscillatoria agardhii	blue-green	Oscillatoriaceae	ES,LE
Oscillatoria amphibia	blue-green	Oscillatoriaceae	ES
Oscillatoria chlorina	blue-green	Oscillatoriaceae	LE
Oscillatoria granulata	blue-green	Oscillatoriaceae	ES
Oscillatoria hamelii	blue-green	Oscillatoriaceae	ES,LE
Oscillatoria limosa	blue-green	Oscillatoriaceae	CK,ES
Oscillatoria prolifica	blue-green	Oscillatoriaceae	LE
Oscillatoria spp.	blue-greens	Oscillatoriaceae	ES,LE
Oscillatoria subbrevis	blue-green	Oscillatoriaceae	CK,ES
Oscillatoria tenuis	blue-green	Oscillatoriaceae	CK,ES
Phormidium tenue	blue-green	Oscillatoriaceae	ES
Raphidiopsis mediterranea	blue-green	Rivulariaceae	LE
Schizothrix calcicola	blue-green	Oscillatoriaceae	CK,ES
Spirulina sp.	blue-green	Rivulariaceae	ES

KINGDOM PROTISTA

DIVISION RHODOPHYTA (red algae)
CLASS RHODOPHYCEAE

Order Bangiales	**Common Name**	**Family**	**Location**
Bangia atropurpurea	red alga	Bangiaceae	LE
DIVISION CHRYSOPHYTA (golden & yellow-green algae)			
CLASS CHRYSOPHYCEAE (chrysophycean algae)			
Order Ochromonadales			
Anthophysa steinii	golden-brown alga	Mallomonadaceae	ES
Anthophysa vegetans	golden-brown alga	Mallomonadaceae	ES
Chrysococcus biporus	golden-brown alga	Ochromonadaceae	ES
Chrysococcus minutus	golden-brown alga	Ochromonadaceae	ES
Chrysococcus rufescens var. *tripora*	golden-brown alga	Ochromonadaceae	ES
Chrysococcus triporus	golden-brown alga	Ochromonadaceae	ES
Chrysococcus spp.	golden-brown algae	Ochromonadaceae	ES
Dinobryon bavaricum	golden-brown alga	Dinobryacae	ES
Dinobryon divergens	golden-brown alga	Dinobryacae	ES
Dinobryon sertularia	golden-brown alga	Dinobryacae	ES
Dinobryon sociale	golden-brown alga	Dinobryacae	ES
Dinobryon sp.	golden-brown alga	Dinobryacae	ES
Epipyxis tabellariae	golden-brown alga	Dinobryacae	ES
Kephryion ovale	golden-brown alga	Ochromonadaceae	ES
Kephryion spirale	golden-brown alga	Ochromonadaceae	LE
Kephryion spp.	golden-brown algae	Ochromonadaceae	ES
Mallomonas acaroides	golden-brown alga	Mallomonadaceae	ES
Mallomonas elegans	golden-brown alga	Mallomonadaceae	ES
Mallomonas intermedia	golden-brown alga	Mallomonadaceae	ES
Microglena sp.	golden-brown alga	Ochromonadaceae	ES
Monas guttula	golden-brown alga	Ochromonadaceae	ES
Monas socialis	golden-brown alga	Ochromonadaceae	ES
Monas sp.	golden-brown alga	Ochromonadaceae	ES
Ochromonas ludibunda	golden-brown alga	Ochromonadaceae	ES
Ochromonas nana	golden-brown alga	Ochromonadaceae	ES
Ochromonas sp.	golden-brown alga	Ochromonadaceae	ES
Physomonas vestita	golden-brown alga	Ochromonadaceae	ES
Pseudokephyrion cylindricum	golden-brown alga	Dinobryacae	ES
Pseudokephyrion entzii f. *granulata*	golden-brown alga	Dinobryacae	ES
Spumella sp.	golden-brown alga	Ochromonadaceae	ES
Stokesiella sp.	golden-brown alga	Dinobryacae	ES
Synura uvella	golden-brown alga	Mallomonadaceae	ES
CLASS XANTHOPHYCEAE (yellow-green algae)			
Order Rhizochloridaceae			
Stipitococcus vasiformis	yellow-green alga	Stipitociccaceae	ES
Order Mischococcales			
Centritractus ellipsoideus	yellow-green alga	Centritractaceae	ES
Goniochloris fallax	yellow-green alga	Pleurochloridaceae	ES
Ophiocytium capitatum var. *longispina*	yellow-green alga	Ophiocytaceae	ES
Pseudostaurastrum hastatum	yellow-green alga	Pleurochloridaceae	ES
Order Vaucheriales			
Vaucheria sp.	yellow-green alga	Vaucheriaceae	ES
CLASS BACILLARIOPHYCEAE (diatoms)			
Order Centrales (centric diatoms)			
Acanthoceras zachariasii	centric diatom	Rhizosoleniaceae	ES
Actinocyclus normanii	centric diatom	Coscinodiscaceae	ES
Aulacoseira alpigena	centric diatom	Melosiraceae	ES
Aulacoseira ambigua	centric diatom	Melosiraceae	ES
Aulacoseira crassipunctata	centric diatom	Melosiraceae	ES

Order Centrales (cont'd)	**Common Name**	**Family**	**Location**
Aulacoseira granulata	centric diatom	Melosiraceae	ES
Aulacoseira granulata var. *angustissima*	centric diatom	Melosiraceae	ES,LE
Aulacoseira islandica	centric diatom	Melosiraceae	E
Aulacoseira italica	centric diatom	Melosiraceae	ES
Aulacoseira spp.	centric diatoms	Melosiraceae	ES
Coscinodiscus sp.	centric diatom	Coscinodiscaceae	ES
Cyclostephanos invisitatus	centric diatom	Thalassiososiraceae	ES
Cyclostephanos tholiformis	centric diatom	Thalassiososiraceae	ES
Cyclotella atomus	centric diatom	Thalassiososiraceae	ES
Cyclotella atomus var. 1	centric diatom	Thalassiososiraceae	ES
Cyclotella meneghiniana	centric diatom	Thalassiososiraceae	ES
Cyclotella meneghiniana var. 1	centric diatom	Thalassiososiraceae	ES
Cyclotella pseudostelligera	centric diatom	Thalassiososiraceae	ES
Cyclotella radiosa	centric diatom	Thalassiososiraceae	ES
Cyclotella stelligera	centric diatom	Thalassiososiraceae	ES
Cyclotella spp.	centric diatoms	Thalassiososiraceae	ES
Melosira varians	centric diatom	Melosiraceae	ES
Rhizosolenia eriensis	centric diatom	Rhizosoleniaceae	ES
Skeletonema potamos	centric diatom	Thalassiososiraceae	ES
Stephanodiscus alpinus	centric diatom	Coscinodiscaceae	ES
Stephanodiscus binderanus	centric diatom	Coscinodiscaceae	ES,LE
Stephanodiscus hantzschii	centric diatom	Coscinodiscaceae	ES
Stephanodiscus minutulus	centric diatom	Coscinodiscaceae	ES
Stephanodiscus nipigonensis	centric diatom	Coscinodiscaceae	ES
Stephanodiscus parvus	centric diatom	Coscinodiscaceae	ES
Stephanodiscus rotula	centric diatom	Coscinodiscaceae	CK,ES,LE
Stephanodiscus subtilis	centric diatom	Coscinodiscaceae	ES
Stephanodiscus sp.	centric diatom	Coscinodiscaceae	ES
Thalassiosira pseudonana	centric diatom	Thalassiososiraceae	ES
Thalassiosira weissflogii	centric diatom	Thalassiososiraceae	ES
Order Pennales (pennate diatoms)			
Achnanthes biasolettiana	pennate diatom	Achnanthaceae	ES
Achnanthes clevei	pennate diatom	Achnanthaceae	ES
Achnanthes conspicua	pennate diatom	Achnanthaceae	CK
Achnanthes grischuna	pennate diatom	Achnanthaceae	ES
Achnanthes hungarica	pennate diatom	Achnanthaceae	ES
Achnanthes lanceolata	pennate diatom	Achnanthaceae	CK,ES
Achnanthes lanceolata ssp. *dubia*	pennate diatom	Achnanthaceae	CK,ES
Achnanthes lanceolata ssp. *lanceolata*	pennate diatom	Achnanthaceae	CK,ES
Achnanthes lanceolata ssp. *l.* var. *boyei*	pennate diatom	Achnanthaceae	ES
Achnanthes laurenburgiana	pennate diatom	Achnanthaceae	ES
Achnanthes minutissima	pennate diatom	Achnanthaceae	CK,ES
Achnanthes minutissima var. *gracillima*	pennate diatom	Achnanthaceae	ES
Achnanthes minutissima var. *minutissima*	pennate diatom	Achnanthaceae	CK
Achnanthes minutissima var. *saprophila*	pennate diatom	Achnanthaceae	ES
Achnanthes minutissima var. 2	pennate diatom	Achnanthaceae	ES
Achnanthes sp.	pennate diatom	Achnanthaceae	CK,ES
Amphilpleura pellucida	pennate diatom	Naviculaceae	CK,ES
Amphora montana	pennate diatom	Cymbellaceae	ES
Amphora ovalis	pennate diatom	Cymbellaceae	ES
Amphora pediculus	pennate diatom	Cymbellaceae	CK,ES
Amphora sp.	pennate diatom	Cymbellaceae	ES
Anomoeoneis brachysira	pennate diatom	Naviculaceae	ES
Anomoeoneis sphaerophora	pennate diatom	Naviculaceae	ES
Asterionella formosa	pennate diatom	Fragilariaceae	ES,LE
Caloneis amphisbaena	pennate diatom	Naviculaceae	CK,ES
Caloneis bacillum	pennate diatom	Naviculaceae	CK,ES
Caloneis clevei	pennate diatom	Naviculaceae	ES
Caloneis molaris	pennate diatom	Naviculaceae	ES

Order Pennales (cont'd)	Common Name	Family	Location
Caloneis schumanniana	pennate diatom	Naviculaceae	ES
Caloneis thermalis	pennate diatom	Naviculaceae	ES
Cocconeis pediculus	pennate diatom	Achnanthaceae	ES
Cocconeis placentula	pennate diatom	Achnanthaceae	CK,ES
Cocconeis placentula var. *euglypta*	pennate diatom	Achnanthaceae	ES
Cocconeis placentula var. *lineata*	pennate diatom	Achnanthaceae	ES
Cylindrotheca gracilis	pennate diatom	Nitzschiacea	ES
Cymatopleura elliptica	pennate diatom	Surirellacea	CK
Cymatopleura solea	pennate diatom	Surirellacea	ES
Cymbella affinis	pennate diatom	Cymbellaceae	ES
Cymbella caespitosa	pennate diatom	Cymbellaceae	ES
Cymbella microcephala	pennate diatom	Cymbellaceae	ES
Cymbella minuta	pennate diatom	Cymbellaceae	CK,ES
Cymbella naviculiformis	pennate diatom	Cymbellaceae	ES
Cymbella prostrata	pennate diatom	Cymbellaceae	CK
Cymbella silesiaca	pennate diatom	Cymbellaceae	CK,ES
Cymbella triangulum	pennate diatom	Cymbellaceae	LE
Cymbella tumida	pennate diatom	Cymbellaceae	CK,ES
Cymbella tumidula	pennate diatom	Cymbellaceae	CK,ES
Cymbella turgidula	pennate diatom	Cymbellaceae	CK,ES
Denticula kuetzingii	pennate diatom	Epithemiacea	ES
Diatoma vulgaris var. *distorta*	pennate diatom	Fragilariaceae	ES
Diatoma mesodon	pennate diatom	Fragilariaceae	ES
Diatoma tenuis	pennate diatom	Fragilariaceae	ES
Diatoma vulgaris	pennate diatom	Fragilariaceae	ES
Entomoneis ornata	pennate diatom	Naviculaceae	LE
Epithemia adnata	pennate diatom	Epithemiacea	ES
Epithemia turgida	pennate diatom	Epithemiacea	ES
Eunotia arcus var. *bidens*	pennate diatom	Eunotiaceae	ES
Eunotia bilunaris var. *bilunaris*	pennate diatom	Eunotiaceae	ES
Eunotia bilunarius var. *mucophila*	pennate diatom	Eunotiaceae	ES
Eunotia denticulata	pennate diatom	Eunotiaceae	ES
Eunotia diodon	pennate diatom	Eunotiaceae	ES
Eunotia exigua	pennate diatom	Eunotiaceae	ES
Eunotia formica	pennate diatom	Eunotiaceae	ES
Eunotia pectinalis	pennate diatom	Eunotiaceae	ES
Eunotia sp.	pennate diatom	Eunotiaceae	ES
Fragilaria capucina	pennate diatom	Fragilariaceae	CK,ES,LE
Fragilaria capucina var. *gracilis*	pennate diatom	Fragilariaceae	ES
Fragilaria capucina var. *radians*	pennate diatom	Fragilariaceae	ES
Fragilaria capucina var. *rumpens*	pennate diatom	Fragilariaceae	CK,ES
Fragilaria capucina var. *vaucheriae*	pennate diatom	Fragilariaceae	CK,ES
Fragilaria construens	pennate diatom	Fragilariaceae	ES
Fragilaria construens f. *venter*	pennate diatom	Fragilariaceae	CK,ES
Fragilaria crotonensis	pennate diatom	Fragilariaceae	ES,LE
Fragilaria fasciculata	pennate diatom	Fragilariaceae	CK,ES
Fragilaria leptostauron var. *martyi*	pennate diatom	Fragilariaceae	ES
Fragilaria parasitica var. *subconstricta*	pennate diatom	Fragilariaceae	ES
Fragilaria pulchella	pennate diatom	Fragilariaceae	ES
Fragilaria tenera	pennate diatom	Fragilariaceae	ES
Fragilaria ulna	pennate diatom	Fragilariaceae	CK,ES
Fragilaria ulna var. *acus*	pennate diatom	Fragilariaceae	ES
Fragilaria ulna var. *danica*	pennate diatom	Fragilariaceae	ES
Fragilaria ulna var. *obtusa*	pennate diatom	Fragilariaceae	CK
Fragilaria ulna var. *oxyrhynchus*	pennate diatom	Fragilariaceae	CK
Fragilaria ulna var. 1	pennate diatom	Fragilariaceae	ES
Fragilaria virescens	pennate diatom	Fragilariaceae	CK,ES
Frustulia rhomboides	pennate diatom	Naviculaceae	ES
Frustulia vulgaris	pennate diatom	Naviculaceae	ES
Gomphonema acuminatum	pennate diatom	Cymbellaceae	ES

Order Pennales (cont'd)	Common Name	Family	Location
Gomphonema affine	pennate diatom	Cymbellaceae	CK,ES
Gomphonema affine var. *elongatum*	pennate diatom	Cymbellaceae	ES
Gomphonema amoenum	pennate diatom	Cymbellaceae	ES
Gomphonema angustatum	pennate diatom	Cymbellaceae	CK,ES
Gomphonema angustatum var. *citera*	pennate diatom	Cymbellaceae	CK
Gomphonema a. var. *sarcophogus*	pennate diatom	Cymbellaceae	ES
Gomphonema angustum	pennate diatom	Cymbellaceae	CK,ES
Gomphonema augar var. *spaerophorum*	pennate diatom	Cymbellaceae	CK
Gomphonema augur	pennate diatom	Cymbellaceae	CK,ES
Gomphonema clavatum	pennate diatom	Cymbellaceae	ES
Gomphonema clevei	pennate diatom	Cymbellaceae	ES
Gomphonema dichotomum	pennate diatom	Cymbellaceae	ES
Gomphonema gracile	pennate diatom	Cymbellaceae	ES
Gomphonema minutum	pennate diatom	Cymbellaceae	ES
Gomphonema minutum f. *lamanense*	pennate diatom	Cymbellaceae	ES
Gomphonema olivaceum	pennate diatom	Cymbellaceae	CK,ES
Gomphonema parvulum	pennate diatom	Cymbellaceae	CK,ES
Gomphonema truncatum	pennate diatom	Cymbellaceae	ES
Gomphonema truncatum var. *elongata*	pennate diatom	Cymbellaceae	ES
Gomphonema sp.	pennate diatom	Cymbellaceae	ES
Gyrosigma acuminatum	pennate diatom	Naviculaceae	CK
Gyrosigma attenuatum	pennate diatom	Naviculaceae	ES
Gyrosigma exilis	pennate diatom	Naviculaceae	ES
Gyrosigma scalproides	pennate diatom	Naviculaceae	ES
Gyrosigma sp.	pennate diatom	Naviculaceae	ES
Hantzschia amphioxys	pennate diatom	Nitzschiacea	ES
Meridion circulare	pennate diatom	Fragilariaceae	CK,ES
Meridion circulare var. *constrictum*	pennate diatom	Fragilariaceae	ES
Navicula absoluta	pennate diatom	Naviculaceae	ES
Navicula agnita	pennate diatom	Naviculaceae	ES
Navicula arvensis	pennate diatom	Naviculaceae	ES
Navicula atomus	pennate diatom	Naviculaceae	ES
Navicula atomus var. *permitis*	pennate diatom	Naviculaceae	ES
Navicula bacillum	pennate diatom	Naviculaceae	ES
Navicula bahusiensis	pennate diatom	Naviculaceae	ES
Navicula capitata	pennate diatom	Naviculaceae	ES
Navicula capitata var. *capitata*	pennate diatom	Naviculaceae	ES
Navicula capitatoradiata	pennate diatom	Naviculaceae	ES
Navicula cincta	pennate diatom	Naviculaceae	ES
Navicula confervacea	pennate diatom	Naviculaceae	ES
Navicula contenta	pennate diatom	Naviculaceae	ES
Navicula cryptocephala	pennate diatom	Naviculaceae	ES
Navicula cryptotenella	pennate diatom	Naviculaceae	CK,ES
Navicula cuspidata	pennate diatom	Naviculaceae	CK,ES
Navicula decussis	pennate diatom	Naviculaceae	CK,ES
Navicula elginensis	pennate diatom	Naviculaceae	CK,ES
Navicula erifuga	pennate diatom	Naviculaceae	ES
Navicula goeppertiana	pennate diatom	Naviculaceae	ES
Navicula goeppertiana var. *goeppertiana*	pennate diatom	Naviculaceae	ES
Navicula goeppertiana var. *monita*	pennate diatom	Naviculaceae	ES
Navicula gregaria	pennate diatom	Naviculaceae	CK,ES
Navicula grunowii var. 1	pennate diatom	Naviculaceae	ES
Navicula halophila	pennate diatom	Naviculaceae	ES
Navicula heimansii	pennate diatom	Naviculaceae	ES
Navicula hustedtii	pennate diatom	Naviculaceae	ES
Navicula ingenua	pennate diatom	Naviculaceae	ES
Navicula insocibilis	pennate diatom	Naviculaceae	ES
Navicula integra	pennate diatom	Naviculaceae	ES
Navicula lanceolata	pennate diatom	Naviculaceae	CK,ES
Navicula menisculus	pennate diatom	Naviculaceae	ES

Order Pennales (cont'd)	Common Name	Family	Location
Navicula menisculus var. *grunowii*	pennate diatom	Naviculaceae	ES
Navicula menisculus var. *upsaliensis*	pennate diatom	Naviculaceae	CK,ES
Navicula minima	pennate diatom	Naviculaceae	CK,ES
Navicula minima var. *pseudofossalis*	pennate diatom	Naviculaceae	ES
Navicula minusculoides	pennate diatom	Naviculaceae	ES
Navicula molestiformis	pennate diatom	Naviculaceae	ES
Navicula monoculata	pennate diatom	Naviculaceae	ES
Navicula mutica	pennate diatom	Naviculaceae	ES
Navicula mutica var. *ventricosa*	pennate diatom	Naviculaceae	ES
Navicula pelliculosa	pennate diatom	Naviculaceae	ES
Navicula praeterita	pennate diatom	Naviculaceae	ES
Navicula pseudolanceolata	pennate diatom	Naviculaceae	ES
Navicula pupula	pennate diatom	Naviculaceae	ES
Navicula pupula var. *aquaeductae*	pennate diatom	Naviculaceae	ES
Navicula pupula var. *rectangularis*	pennate diatom	Naviculaceae	ES
Navicula pygmaea	pennate diatom	Naviculaceae	ES
Navicula radiosa	pennate diatom	Naviculaceae	ES
Navicula recens	pennate diatom	Naviculaceae	ES
Navicula rhynchocephala	pennate diatom	Naviculaceae	ES
Navicula salinarum	pennate diatom	Naviculaceae	CK,ES
Navicula saprophila	pennate diatom	Naviculaceae	CK,ES
Navicula schroeterii	pennate diatom	Naviculaceae	ES
Navicula seminulum	pennate diatom	Naviculaceae	ES
Navicula similis	pennate diatom	Naviculaceae	ES
Navicula splendicula	pennate diatom	Naviculaceae	ES
Navicula subminuscula	pennate diatom	Naviculaceae	ES
Navicula submolesta	pennate diatom	Naviculaceae	ES
Navicula tenelloides	pennate diatom	Naviculaceae	ES
Navicula tenera	pennate diatom	Naviculaceae	ES
Navicula tripunctata	pennate diatom	Naviculaceae	CK,ES
Navicula tripunctata var. *schizonemoides*	pennate diatom	Naviculaceae	ES
Navicula trivialis	pennate diatom	Naviculaceae	ES
Navicula vaucherie	pennate diatom	Naviculaceae	ES
Navicula veneta	pennate diatom	Naviculaceae	CK,ES
Navicula viridula	pennate diatom	Naviculaceae	ES
Navicula viridula var. *germainii*	pennate diatom	Naviculaceae	CK,ES
Navicula viridula var. *rostellata*	pennate diatom	Naviculaceae	CK,ES
Navicula viridula var. 1	pennate diatom	Naviculaceae	ES
Navicula spp.	pennate diatoms	Naviculaceae	ES
Nedium affine	pennate diatom	Naviculaceae	ES
Nedium dubium	pennate diatom	Naviculaceae	ES
Nitzschia acicularis	pennate diatom	Nitzschiacea	ES
Nitzschia acidoclinata	pennate diatom	Nitzschiacea	ES
Nitzschia acuminata	pennate diatom	Nitzschiacea	ES
Nitzschia admissoides	pennate diatom	Nitzschiacea	CK
Nitzschia agnita	pennate diatom	Nitzschiacea	ES
Nitzschia amphibia	pennate diatom	Nitzschiacea	CK,ES
Nitzschia angustata	pennate diatom	Nitzschiacea	ES
Nitzschia angustatula	pennate diatom	Nitzschiacea	ES
Nitzschia angustiforaminata	pennate diatom	Nitzschiacea	ES
Nitzschia bita?	pennate diatom	Nitzschiacea	CK
Nitzschia brevissima	pennate diatom	Nitzschiacea	ES
Nitzschia capitellata	pennate diatom	Nitzschiacea	ES
Nitzschia clausii	pennate diatom	Nitzschiacea	ES
Nitzschia closterium	pennate diatom	Nitzschiacea	ES
Nitzschia communis	pennate diatom	Nitzschiacea	CK,ES
Nitzschia commutatoides	pennate diatom	Nitzschiacea	ES
Nitzschia compressa var. *vexans*	pennate diatom	Nitzschiacea	ES
Nitzschia constricta	pennate diatom	Nitzschiacea	CK
Nitzschia dissipata	pennate diatom	Nitzschiacea	CK,ES

Order Pennales (cont'd)	Common Name	Family	Location
Nitzschia dissipata var. *media*	pennate diatom	Nitzschiacea	ES
Nitzschia dubia	pennate diatom	Nitzschiacea	ES
Nitzschia filiformis	pennate diatom	Nitzschiacea	ES
Nitzschia fonticola	pennate diatom	Nitzschiacea	ES
Nitzschia frustulum	pennate diatom	Nitzschiacea	ES
Nitzschia frustulum var. *perpusilla*	pennate diatom	Nitzschiacea	ES
Nitzschia fruticosa	pennate diatom	Nitzschiacea	ES
Nitzschia gracilis	pennate diatom	Nitzschiacea	ES
Nitzschia hantzschiana	pennate diatom	Nitzschiacea	ES
Nitzschia hungarica	pennate diatom	Nitzschiacea	ES
Nitzschia inconspicua	pennate diatom	Nitzschiacea	ES
Nitzschia intermedia	pennate diatom	Nitzschiacea	CK,ES
Nitzschia levidensis	pennate diatom	Nitzschiacea	ES
Nitzschia linearis	pennate diatom	Nitzschiacea	ES
Nitzschia linearis var. *subtilis*	pennate diatom	Nitzschiacea	ES
Nitzschia littoralis	pennate diatom	Nitzschiacea	ES
Nitzschia microcephala	pennate diatom	Nitzschiacea	ES
Nitzschia nereidis	pennate diatom	Nitzschiacea	ES
Nitzschia palea	pennate diatom	Nitzschiacea	CK,ES
Nitzschia palea var. *minuta*	pennate diatom	Nitzschiacea	ES
Nitzschia paleacea	pennate diatom	Nitzschiacea	ES
Nitzschia parvula	pennate diatom	Nitzschiacea	ES
Nitzschia perspicua	pennate diatom	Nitzschiacea	ES
Nitzschia plana	pennate diatom	Nitzschiacea	ES
Nitzschia pusilla	pennate diatom	Nitzschiacea	CK,ES
Nitzschia recta	pennate diatom	Nitzschiacea	CK,ES
Nitzschia reversa	pennate diatom	Nitzschiacea	ES
Nitzschia sigma	pennate diatom	Nitzschiacea	ES
Nitzschia sigmoidea	pennate diatom	Nitzschiacea	CK,ES
Nitzschia sinuata	pennate diatom	Nitzschiacea	ES
Nitzschia sinuata var. *tabellaria*	pennate diatom	Nitzschiacea	CK,ES
Nitzschia sociabilis	pennate diatom	Nitzschiacea	ES
Nitzschia solita	pennate diatom	Nitzschiacea	ES
Nitzschia spiculum	pennate diatom	Nitzschiacea	ES
Nitzschia stricta	pennate diatom	Nitzschiacea	ES
Nitzschia subacicularis	pennate diatom	Nitzschiacea	ES
Nitzschia supralitorea	pennate diatom	Nitzschiacea	ES
Nitzschia tropica	pennate diatom	Nitzschiacea	ES
Nitzschia tryblionella	pennate diatom	Nitzschiacea	ES
Nitzschia tubicola	pennate diatom	Nitzschiacea	ES
Nitzschia valga	pennate diatom	Nitzschiacea	ES
Pinnularia abaujensis var. *rostrata*	pennate diatom	Naviculaceae	ES
Pinnularia borealis	pennate diatom	Naviculaceae	LE
Pinnularia intermedia	pennate diatom	Naviculaceae	ES
Pinnularia microstauron	pennate diatom	Naviculaceae	ES
Pinnularia microstauron var. *brebissonii*	pennate diatom	Naviculaceae	ES
Pinnularia microstauron var. *b.* f. *diminuta*	pennate diatom	Naviculaceae	ES
Pinnularia nodosa	pennate diatom	Naviculaceae	ES
Pinnularia obscura	pennate diatom	Naviculaceae	ES
Pinnularia stomatophora	pennate diatom	Naviculaceae	ES
Pinnularia viridis	pennate diatom	Naviculaceae	ES
Pinnularia sp.	pennate diatom	Naviculaceae	ES
Plagiotropis lepidoptera var. *probosidea*	pennate diatom	Naviculaceae	ES
Pleurosigma delicatulum	pennate diatom	Naviculaceae	CK
Reimeria sinuata	pennate diatom	Cymbellaceae	CK,ES
Rhoicosphenia abbreviata	pennate diatom	Achnanthaceae	CK,ES
Stauroneis anceps	pennate diatom	Naviculaceae	ES
Stauroneis kriegeri	pennate diatom	Naviculaceae	ES
Stauroneis phoenicenteron	pennate diatom	Naviculaceae	ES
Stauroneis smithii	pennate diatom	Naviculaceae	ES

Order Pennales (cont'd)	Common Name	Family	Location
Stauroneis thermicola	pennate diatom	Naviculaceae	ES
Surirella angusta	pennate diatom	Surirellacea	ES
Surirella brebissonii var. *kuetzingii*	pennate diatom	Surirellacea	ES
Surirella minuta	pennate diatom	Surirellacea	CK,ES
Surirella ovalis	pennate diatom	Surirellacea	ES
Surirella suecica	pennate diatom	Surirellacea	ES
Surirella tenera	pennate diatom	Surirellacea	ES
Surirella turgida	pennate diatom	Surirellacea	ES
Tabellaria fenestrata	pennate diatom	Fragilariaceae	ES
Tabellaria sp.	pennate diatom	Fragilariaceae	ES
DIVISION PYRRHOPHYTA (fire algae)			
CLASS DINOPHYCEAE (dinoflagellates)			
Order Gymnodiniales			
Gymnodinium aeruginosun	dinoflagellate	Gymnodiniaceae	ES
Gymnodinium helveticum	dinoflagellate	Gymnodiniaceae	ES
Gymnodinium palustre	dinoflagellate	Gymnodiniaceae	ES
Gymnodinium spp.	dinoflagellates	Gymnodiniaceae	CK,ES
Katodinium fungiforme	dinoflagellate	Gymnodiniaceae	ES
Order Peridiniales			
Ceratium hirundinella	dinoflagellate	Ceratiaceae	ES,LE
Ceratium sp.	dinoflagellate	Ceratiaceae	ES
Glenodinium sp.	dinoflagellate	Peridiniaceae	ES
Perdiniopsis quadridens	dinoflagellate	Peridiniaceae	ES
Woloszynskia coronata	dinoflagellate	Lophodiniaceae	ES
DIVISION CRYPTOPHYTA (cryptomonads)			
CLASS CRYPTOPHYCEAE			
Order Cryptomonadales			
Chilomonas sp.	cryptomonad	Cryptomonadaceae	ES
Chroomonas norstedtii	cryptomonad	Cryptomonadaceae	ES
Chroomonas sp.	cryptomonad	Cryptomonadaceae	ES
Cryptomonas compressa	cryptomonad	Cryptomonadaceae	ES
Cryptomonas erosa	cryptomonad	Cryptomonadaceae	ES
Cryptomonas erosa var. *reflexa*	cryptomonad	Cryptomonadaceae	CK
Cryptomonas marssonii	cryptomonad	Cryptomonadaceae	ES
Cryptomonas obovata	cryptomonad	Cryptomonadaceae	ES
Cryptomonas ovata	cryptomonad	Cryptomonadaceae	ES
Cryptomonas reflexa	cryptomonad	Cryptomonadaceae	ES
Cryptomonas tenuis	cryptomonad	Cryptomonadaceae	ES
Cryptomonas tetrapyrenoidosa	cryptomonad	Cryptomonadaceae	ES
Cryptomonas spp.	cryptomonads	Cryptomonadaceae	ES
Cyathomonas truncata	cryptomonad	Cyathomonadaceae	ES
Cyathomonas sp.	cryptomonad	Cyathomonadaceae	ES
Planonephros parvula	cryptomonad	Hemiselmidaceae	ES
Rhodomonas lacustris	cryptomonad	Cryptomonadaceae	ES
Rhodomonas lens	cryptomonad	Cryptomonadaceae	ES
Rhodomonas minuta	cryptomonad	Cryptomonadaceae	ES
Rhodomonas m. var. *nannoplanctonica*	cryptomonad	Cryptomonadaceae	ES,LE
Rhodomonas spp.	cryptomonads	Cryptomonadaceae	CK,ES
DIVISION EUGLENOPHYTA (euglenoids)			
CLASS EUGLENOPHYCEAE			
Order Euglenales (green euglenas)			
Ascoglena vaginicola	euglenoid	Euglenaceae	ES
Ascoglena sp.	euglenoid	Euglenaceae	ES
Astasia klebsii	euglenoid	Astaciaceae	ES
Astasia spp.	euglenoids	Astaciaceae	ES
Euglena acus	euglenoid	Euglenaceae	ES
Euglena bellovacensis	euglenoid	Euglenaceae	ES

Order Euglenales (cont'd)	Common Name	Family	Location
Euglena deses	euglenoid	Euglenaceae	ES
Euglena ehrenbergii	euglenoid	Euglenaceae	ES
Euglena elastica	euglenoid	Euglenaceae	ES
Euglena fronsundulata	euglenoid	Euglenaceae	ES
Euglena gasterosteus	euglenoid	Euglenaceae	CK,ES
Euglena gracilis	euglenoid	Euglenaceae	ES
Euglena ignobilis	euglenoid	Euglenaceae	ES
Euglena minima	euglenoid	Euglenaceae	ES
Euglena oxyuris	euglenoid	Euglenaceae	ES
Euglena oxyuris var. *minima*	euglenoid	Euglenaceae	ES
Euglena oxyuris var. *minor*	euglenoid	Euglenaceae	ES
Euglena pisciformis	euglenoid	Euglenaceae	ES
Euglena proxima	euglenoid	Euglenaceae	ES
Euglena spathirhyncha	euglenoid	Euglenaceae	ES
Euglena spirogyra	euglenoid	Euglenaceae	ES
Euglena tripteris	euglenoid	Euglenaceae	ES
Euglena vermiforis	euglenoid	Euglenaceae	ES
Euglena spp.	euglenoids	Euglenaceae	CK,ES
Lepocinclis ovum	euglenoid	Euglenaceae	ES
Lepocinclis ovum f. *typica*	euglenoid	Euglenaceae	ES
Lepocinclis ovum var. *deflandriana*	euglenoid	Euglenaceae	ES
Lepocinclis ovum var. *dimidio-minor*	euglenoid	Euglenaceae	ES
Lepocinclis ovum var. *ovata* f. *ecaudata*	euglenoid	Euglenaceae	ES
Lepocinclis texta f. *minor*	euglenoid	Euglenaceae	ES
Lepocinclis spp.	euglenoids	Euglenaceae	CK,ES
Phacus acuminatus	euglenoid	Euglenaceae	CK,ES
Phacus arnoldi	euglenoid	Euglenaceae	ES
Phacus caudatus	euglenoid	Euglenaceae	ES
Phacus contortus	euglenoid	Euglenaceae	ES
Phacus curvicauda	euglenoid	Euglenaceae	ES
Phacus helikoides	euglenoid	Euglenaceae	ES
Phacus longicauda	euglenoid	Euglenaceae	ES
Phacus obicularis	euglenoid	Euglenaceae	ES
Phacus pleuronectes	euglenoid	Euglenaceae	ES
Phacus pseudonordstedii	euglenoid	Euglenaceae	ES
Phacus rudicula	euglenoid	Euglenaceae	ES
Phacus tortus	euglenoid	Euglenaceae	ES
Phacus triqueter	euglenoid	Euglenaceae	ES
Phacus sp.	euglenoid	Euglenaceae	ES
Scytomonas sp.	euglenoid	Astaciaceae	ES
Strombomonas acuminata	euglenoid	Euglenaceae	ES
Strombomonas fluviatilis	euglenoid	Euglenaceae	ES
Strombomonas gibberosa	euglenoid	Euglenaceae	ES
Strombomonas longicauda	euglenoid	Euglenaceae	ES
Strombomonas schauinslandii	euglenoid	Euglenaceae	ES
Strombomonas verrucosa var. *zmiewika*	euglenoid	Euglenaceae	ES
Strombomonas sp.	euglenoid	Euglenaceae	ES
Trachelomonas abrupta var. *minor*	euglenoid	Euglenaceae	ES
Trachelomonas armata	euglenoid	Euglenaceae	ES
Trachelomonas bulla	euglenoid	Euglenaceae	ES
Trachelomonas crebea	euglenoid	Euglenaceae	ES
Trachelomonas granulosa	euglenoid	Euglenaceae	ES
Trachelomonas hispida	euglenoid	Euglenaceae	ES
Trachelomonas horrida	euglenoid	Euglenaceae	ES
Trachelomonas lacustris	euglenoid	Euglenaceae	ES
Trachelomonas oblonga	euglenoid	Euglenaceae	ES
Trachelomonas oblonga var. *attenuata*	euglenoid	Euglenaceae	ES
Trachelomonas oblonga var. *truncata*	euglenoid	Euglenaceae	ES
Trachelomonas o. var. *umbilicophora*	euglenoid	Euglenaceae	ES
Trachelomonas planctonica	euglenoid	Euglenaceae	ES

Order Euglenales (cont'd)	**Common Name**	**Family**	**Location**
Trachelomonas scabra	euglenoid	Euglenaceae	ES
Trachelomonas spiralis	euglenoid	Euglenaceae	ES
Trachelomonas superba	euglenoid	Euglenaceae	ES
Trachelomonas varians	euglenoid	Euglenaceae	ES
Trachelomonas volvocina	euglenoid	Euglenaceae	ES
Trachelomonas volvocina var. *minuta*	euglenoid	Euglenaceae	ES
Trachelomonas spp.	euglenoids	Euglenaceae	ES
Urceolus ovatus	euglenoid	Astaciaceae	ES
Urceolus sabulosus	euglenoid	Astaciaceae	ES
Order Rhabdomonadales			
Menoidium gibbum	euglenoid	Rhabdomonaceae	ES
Rhabdomonas sp.	euglenoid	Rhabdomonaceae	ES
DIVISION CHLOROPHYTA (green algae)			
CLASS CHLOROPHYCEAE			
Order Volvocales			
Carteria bourrellyi	green alga	Chlamydomonadaceae	ES
Carteria globosa	green alga	Chlamydomonadaceae	ES
Carteria wisconsinensis	green alga	Chlamydomonadaceae	CK,ES
Carteria sp.	green alga	Chlamydomonadaceae	ES
Chlamydomonas globosa	green alga	Chlamydomonadaceae	CK,ES
Chlamydomonas gracilis	green alga	Chlamydomonadaceae	ES
Chlamydomonas monadina	green alga	Chlamydomonadaceae	ES
Chlamydomonas reinhardtii	green alga	Chlamydomonadaceae	ES
Chlamydomonas subasymmetrica	green alga	Chlamydomonadaceae	ES
Chlamydomonas spp.	green algae	Chlamydomonadaceae	CK,ES,LE
Chlamydonephris excavata	green alga	Chlamydomonadaceae	ES
Chlorogonium elongatum	green alga	Chlamydomonadaceae	ES
Chlorogonium euchlorum	green alga	Chlamydomonadaceae	ES
Chlorogonium hyalinum	green alga	Chlamydomonadaceae	ES
Eudorina elegans	green alga	Volvocaceae	LE
Haematococcus pluvialis	green alga	Chlamydomonadaceae	ES
Pandorinamorum	green alga	Volvocaceae	ES
Pandorina sp.	green alga	Volvocaceae	ES
Pedinopera sp.	green alga	Phacotaceae	ES
Phacotus lenticularis	green alga	Phacotaceae	ES
Phacotus sp.	green alga	Phacotaceae	ES
Pteromonas angulosa	green alga	Phacotaceae	ES
Pteromonas sp.	green alga	Phacotaceae	ES
Sphaerellopsis spp.	green algae	Chlamydomonadaceae	ES
Volvox sp.	green alga	Volvocaceae	ES
Order Tetrasporales			
Chlamydocapsa ampla	green alga	Palmellaceae	CK,ES
Chlamydocapsa planctonica	green alga	Palmellaceae	ES
Chlamydocapsa sp.	green alga	Palmellaceae	ES
Gloeocystis vesiculosa	green alga	Palmellaceae	CK,ES
Pseudosphaerocystis lacustris	green alga	Palmellaceae	CK,ES
Order Chlorococcales			
Actinastrum hantzschii	green alga	Scenedesmaceae	ES
Ankistrodesmus falcatus	green alga	Oocystaceae	ES
Ankistrodesmus stipitatus	green alga	Oocystaceae	ES
Ankyra judayi	green alga	Chlorococcaceae	ES
Characium curvatum	green alga	Chlorococcaceae	ES
Characium sp.	green alga	Chlorococcaceae	ES
Chlorococcum sp.	green alga	Chlorococcaceae	ES
Closteriopsis acicularis	green alga	Oocystaceae	ES
Coelastrum astroidenum	green alga	Scenedesmaceae	ES
Coelastrum cambricum	green alga	Scenedesmaceae	ES

Order Chlorococcales (cont'd)	Common Name	Family	Location
Coelastrum microporum	green alga	Scenedesmaceae	ES
Coelastrum pseucomicroporum	green alga	Scenedesmaceae	ES
Coelastrum sp.	green alga	Scenedesmaceae	ES
Crucigenia fenestrata	green alga	Scenedesmaceae	ES
Crucigenia mucronata	green alga	Scenedesmaceae	ES
Crucigenia quadrata	green alga	Scenedesmaceae	ES
Crucigenia tetrapedia	green alga	Scenedesmaceae	ES
Crucigeniella apiculata	green alga	Scenedesmaceae	ES
Crucigeniella rectangularis	green alga	Scenedesmaceae	ES
Dictyosphaerium puchellum	green alga	Dictyosphaeriaceae	ES
Didymocystis inconspicua	green alga	Scenedesmaceae	ES
Didymocystis planctonicus	green alga	Scenedesmaceae	ES
Didymocystis sp.	green alga	Scenedesmaceae	ES
Didymogenes palatina	green alga	Scenedesmaceae	ES
Franceia droescheri	green alga	Oocystaceae	ES
Golenkinia radiata	green alga	Micractiniaceae	ES
Golenkiniopsis sp.	green alga	Micractiniaceae	ES
Kirchneriella contorta var. *contorta*	green alga	Oocystaceae	ES
Kirchneriella contorta var. *elegans*	green alga	Oocystaceae	ES
Kirchneriella lunaris	green alga	Oocystaceae	ES
Kirchneriella sp.	green alga	Oocystaceae	ES
Korshikoviella limnetica	green alga	Chlorococcaceae	ES
Lagerheimia balatonica	green alga	Oocystaceae	ES
Lagerheimia ciliata	green alga	Oocystaceae	ES
Lagerheimia citriformis	green alga	Oocystaceae	ES
Lagerheimia genevensis	green alga	Oocystaceae	ES
Lagerheimia marssonii	green alga	Oocystaceae	ES
Lagerheimia subsalsa	green alga	Oocystaceae	ES
Lagerheimia wratislawiensis	green alga	Oocystaceae	ES
Micractinium pusillum	green alga	Micractiniaceae	ES
Monoraphidium arcuatum	green alga	Oocystaceae	ES,LE
Monoraphidium circinale	green alga	Oocystaceae	ES
Monoraphidium contortum	green alga	Oocystaceae	ES
Monoraphidium c. var. *convolutum*	green alga	Oocystaceae	ES
Monoraphidium griffithii	green alga	Oocystaceae	ES
Monoraphidium komarkovae	green alga	Oocystaceae	ES
Monoraphidium mirabile	green alga	Oocystaceae	ES
Monoraphidium sp.	green alga	Oocystaceae	ES
Neodesmus danubialis	green alga	Scenedesmaceae	ES
Nephrochlamys subsolitaria	green alga	Oocystaceae	ES
Nephrochlamys spp.	green algae	Oocystaceae	ES
Oocystis lacustris	green alga	Oocystaceae	ES,LE
Oocystis novae-semliae	green alga	Oocystaceae	ES
Oocystis parva	green alga	Oocystaceae	ES
Oocystis pusilla	green alga	Oocystaceae	ES
Oocystis sp.	green alga	Oocystaceae	ES
Pediastrum boryanum	green alga	Hydrodictyaceae	ES
Pediastrum duplex	green alga	Hydrodictyaceae	ES
Pediastrum duplex var. *duplex*	green alga	Hydrodictyaceae	ES
Pediastrum duplex var. *reticulatum*	green alga	Hydrodictyaceae	ES
Pediastrum simplex	green alga	Hydrodictyaceae	ES
Pediastrum simplex var. *biwaense*	green alga	Hydrodictyaceae	ES
Pediastrum simplex var. *echinulatum*	green alga	Hydrodictyaceae	ES
Pediastrum simplex var. *sturmii*	green alga	Hydrodictyaceae	ES
Pediastrum tetras	green alga	Hydrodictyaceae	ES
Pediastrum tetras var. *tetraodon*	green alga	Hydrodictyaceae	ES
Pediastrum sp.	green alga	Hydrodictyaceae	ES
Quadrigula closteroides	green alga	Oocystaceae	ES
Quadrigula lacustris	green alga	Oocystaceae	ES
Scenedesmus acuminatus	green alga	Scenedesmaceae	ES

Order Chlorococcales (cont'd)	Common Name	Family	Location
Scenedesmus acuminatus var. *minor*	green alga	Scenedesmaceae	ES
Scenedesmus armatus	green alga	Scenedesmaceae	ES
Scenedesmus bicaudatus	green alga	Scenedesmaceae	ES
Scenedesmus bijuga	green alga	Scenedesmaceae	ES
Scenedesmus bijuga var. *alternans*	green alga	Scenedesmaceae	ES
Scenedesmus brevispina	green alga	Scenedesmaceae	ES
Scenedesmus denticulatus	green alga	Scenedesmaceae	ES
Scenedesmus dimorphus	green alga	Scenedesmaceae	CK,ES
Scenedesmus hystrix	green alga	Scenedesmaceae	ES
Scenedesmus longispina	green alga	Scenedesmaceae	ES
Scenedesmus opoliensis	green alga	Scenedesmaceae	CK,ES
Scenedesmus quadricauda	green alga	Scenedesmaceae	ES
Scenedesmus quadricauda var. *longispina*	green alga	Scenedesmaceae	ES
Scenedesmus sempervirens	green alga	Scenedesmaceae	ES
Scenedesmus serratus	green alga	Scenedesmaceae	ES
Scenedesmus smithii	green alga	Scenedesmaceae	ES
Scenedesmus sooi?	green alga	Scenedesmaceae	ES
Scenedesmus subspicatus	green alga	Scenedesmaceae	ES
Scenedesmus verrucosus	green alga	Scenedesmaceae	ES
Scenedesmus spp.	green algae	Scenedesmaceae	CK,ES
Schroederia indica	green alga	Chlorococcaceae	LE
Schroederia robusta	green alga	Chlorococcaceae	ES
Schroederia setigera	green alga	Chlorococcaceae	ES
Schroederia spiralis	green alga	Chlorococcaceae	ES
Selenastrum capricornutum	green alga	Oocystaceae	ES
Selenastrum sp.	green alga	Oocystaceae	ES
Tetraedron caudatum	green alga	Chlorococcaceae	ES
Tetraedron incus	green alga	Chlorococcaceae	ES
Tetraedron minimum	green alga	Chlorococcaceae	CK,ES
Tetraedron muticum	green alga	Chlorococcaceae	ES
Tetraedron regulare	green alga	Chlorococcaceae	ES
Tetraedron trigonum var. *gracile*	green alga	Chlorococcaceae	ES
Tetrastrum elegans	green alga	Scenedesmaceae	ES
Tetrastrum glabrum	green alga	Scenedesmaceae	CK,ES
Tetrastrum heteracanthum	green alga	Scenedesmaceae	ES
Tetrastrum heteracanthum (*elegans* f.)	green alga	Scenedesmaceae	ES
Tetrastrum punctatum	green alga	Scenedesmaceae	ES
Tetrastrum staurogeniaeforme	green alga	Scenedesmaceae	ES
Treubaria quadrispina	green alga	Oocystaceae	ES
Treubaria schmidlei	green alga	Oocystaceae	ES
Treubaria triappendiculata	green alga	Oocystaceae	ES
Willea irregularis	green alga	Scenedesmaceae	ES
Order Oedogoniales			
Oedogonium sp.	green alga	Oedogoniaceae	ES
Order Chaetophorales			
Desmococcus olivaceus	green alga	Chaetophoraceae	CK
Draparnaldia glomerata	green alga	Chaetophoraceae	CK,ES
Stigeoclonium farctum	green alga	Chaetophoraceae	ES
Stigeoclonium sp.	green alga	Chaetophoraceae	ES
Stigeoclonium tenue	green alga	Chaetophoraceae	ES
Order Ulotrichales			
Microspora sp.	green alga	Microsporaceae	ES
Microspora stagnorum	green alga	Microsporaceae	ES
Radiofilum conjunctivum	green alga	Ulotrichaceae	CK
Ulothrix sp.	green alga	Ulotrichaceae	ES
Order Ulotrichales (cont'd)			
Ulothrix tenerrima	green alga	Ulotrichaceae	CK
Ulothrix tenuissima	green alga	Ulotrichaceae	CK

Order Cladophorales	Common Name	Family	Location
Cladophora glomerata	green alga	Cladophoraceae	ES,LE
Rhizoclonium hieroglyphicum	green alga	Cladophoraceae	CK
Order Zygnematales			
Closterium aciculare var. *aciculare*	green alga, desmid	Desmidiaceae	ES
Closterium acutum var. *acutum*	green alga, desmid	Desmidiaceae	ES
Closterium acutum var. *variabile*	green alga, desmid	Desmidiaceae	ES
Closterium gracile var. *gracile*	green alga, desmid	Desmidiaceae	ES
Closterium intermedium	green alga, desmid	Desmidiaceae	CK
Closterium limneticum var. *limneticum*	green alga, desmid	Desmidiaceae	ES
Closterium macilentum var. *macilentum*	green alga, desmid	Desmidiaceae	ES
Closterium moniliferum var. *moniliferum*	green alga, desmid	Desmidiaceae	ES
Closterium spp.	green algae, desmids	Desmidiaceae	ES
Cosmarium formosulum	green alga, desmid	Desmidiaceae	ES
Cosmarium granatum	green alga, desmid	Desmidiaceae	ES
Cosmarium granatum var. *granatum*	green alga, desmid	Desmidiaceae	ES
Cosmarium granulatum?	green alga, desmid	Desmidiaceae	ES
Cosmarium spp.	green algae, desmids	Desmidiaceae	ES
Mougeotia sp.	green alga	Zygnemataceae	ES
Spirogyra sp.	green alga	Zygnemataceae	CK,ES
Staurastrum gracile	green alga, desmid	Desmidiaceae	ES
	KINGDOM FUNGI		
DIVISION MYXOMYCOTA (mucus molds)			
CLASS MYXOMYCETES (true slime molds)			
Order Physarales (physar slimes)			
Badhamia affinis	slime mold	Physaraceae	RE
Craterium minimum	slime mold	Physaraceae	RE
Diderma crustaceum	slime mold	Didymiaceae	RE
Diderma hemisphericum	slime mold	Didymiaceae	RE
Diderma reticulatum	slime mold	Didymiaceae	RE
Didymium crustaceum	slime mold	Didymiaceae	RE
Didymium iridis	slime mold	Didymiaceae	RE
Didymium melanospermum	slime mold	Didymiaceae	RE
Didymium squamulosum	slime mold	Didymiaceae	RE
Fuligo cinerea	slime mold	Physaraceae	RE
Fuligo violacea	slime mold	Physaraceae	RE
Mucilago spongiosa	slime mold	Didymiaceae	RE
Physarella oblonga	slime mold	Physaraceae	RE
Physarum nutans	slime mold	Physaraceae	RE
Physarum vernum	slime mold	Physaraceae	RE
Physarum viride	slime mold	Physaraceae	RE
Physarum viride var. *incanum*	slime mold	Physaraceae	RE
Tilmadoche alba	slime mold	Physaraceae	RE
Order Liceales (lice slimes)			
Cribraria intricata	slime mold	Cribrariaceae	RE
Dictydium cancellatum	Japanese-lantern slime	Cribrariaceae	RE
Lindbladia tubulina	slime mold	Cribrariaceae	RE
Lycogala epidendrum	wolf's-milk slime	Reticulariaceae	RE
Lycogala flavo-fuscum	slime mold	Reticulariaceae	RE
Reticularia splendens	slime mold	Reticulariaceae	RE
Tubifera ferruginosa	red raspberry slime	Reticulariaceae	RE
Tubifera microsperma	slime mold	Reticulariaceae	RE
Order Trichiales (trichi slimes)			
Acryodes incarnata	slime mold	Trichiaceae	RE
Arcyria cinerea	slime mold	Trichiaceae	RE

Order Trichiales (cont'd)	Common Name	Family	Location
Arcyria denudata	carnival candy slime	Trichiaceae	RE
Arcyria incarnata	slime mold	Trichiaceae	RE
Arcyria nutans	slime mold	Trichiaceae	RE
Calonema aureum	slime mold	Trichiaceae	RE
Hemitrichia clavata	yellow-fuzz cone slime	Trichiaceae	RE
Hemitrichia intorta	slime mold	Trichiaceae	RE
Hemitrichia stipitata	slime mold	Trichiaceae	RE
Hemitrichia vesparium	slime mold	Trichiaceae	RE
Lachnobolus globosus	slime mold	Trichiaceae	RE
Ophiotheca wrightii	slime mold	Trichiaceae	RE
Perichæna quadrata	slime mold	Trichiaceae	RE
Trichia inconspicua	slime mold	Trichiaceae	RE
Order Stemonitales (stemonit slimes)			
Comatichia laxa	slime mold	Stemonitaceae	RE
Comatichia pulchella	slime mold	Stemonitaceae	RE
Comatricha stemonitis	slime mold	Stemonitaceae	RE
Diachea leucopodia	white-footed slime	Stemonitaceae	RE
Lamproderma arcyrionema	slime mold	Stemonitaceae	RE
Stemonitis fenestrata	slime mold	Stemonitaceae	RE
Stemonitis fusca	slime mold	Stemonitaceae	RE
Stemonitis herbatica	slime mold	Stemonitaceae	RE
Stemonitis maxima	slime mold	Stemonitaceae	RE
Stemonitis smithii	slime mold	Stemonitaceae	RE
DIVISION PHYCOMYCOTA (algal fungi)			
CLASS CHYTRIDIOMYCETES (chytrids)			
Order Chytridiales			
Entophlyctis aurea	water mold	Phlyctidiaceae	LE,RE
Rozella allomycis	water mold	Olpidiaceae	LE,RE
Synchytrium decipiens	water mold	Synchytriaceae	LE,RE
Order Blastocladiales			
Allomyces arbuscula	water mold	Blastocladiaceae	LE,RE
Blastocladia globosa	water mold	Blastocladiaceae	LE,RE
Blastocladia pringsheimii	water mold	Blastocladiaceae	LE,RE
Blastocladia ramosa	water mold	Blastocladiaceae	LE,RE
Blastocladia simplex	water mold	Blastocladiaceae	LE,RE
Blastocladia tenuis	water mold	Blastocladiaceae	LE,RE
Order Monoblepharidales			
Gonapodya prolifera	water mold	Gonapodyaceae	LE,RE
Monoblepharis sp.	water mold	Monoblepharidaceae	LE,RE
CLASS OOMYCETES (egg fungi)			
Order Saprolegniaceae			
Achlya americana	water mold	Saprolegniaceae	LE,RE
Achlya bisexualis	water mold	Saprolegniaceae	LE,RE
Achlya debaryana	water mold	Saprolegniaceae	LE,RE
Achlya dubia	water mold	Saprolegniaceae	LE,RE
Achlya flagellata	water mold	Saprolegniaceae	LE,RE
Achlya klebsiana	water mold	Saprolegniaceae	LE,RE
Achlya polyandra	water mold	Saprolegniaceae	LE,RE
Achlya prolifera	water mold	Saprolegniaceae	LE,RE
Achlya proliferoides	water mold	Saprolegniaceae	LE,RE
Achlya rodrigueziana	water mold	Saprolegniaceae	LE,RE
Achlya sp.	water mold	Saprolegniaceae	LE,RE
Aphanomyces euteiches	water mold	Saprolegniaceae	LE,RE
Aphanomyces laevis	water mold	Saprolegniaceae	LE,RE
Aphanomyces scaber	water mold	Saprolegniaceae	LE,RE
Aphanomyces sp.	water mold	Saprolegniaceae	LE,RE
Dictyuchus anomalus	water mold	Saprolegniaceae	LE,RE

Order Saprolegniaceae (cont'd)	Common Name	Family	Location
Dictyuchus missouriensis	water mold	Saprolegniaceae	LE,RE
Dictyuchus monosporus	water mold	Saprolegniaceae	LE,RE
Dictyuchus pseudodictyon	water mold	Saprolegniaceae	LE,RE
Dictyuchus sp.	water mold	Saprolegniaceae	LE,RE
Geolegnia inflata	water mold	Saprolegniaceae	LE,RE
Isoachlya sp.?	water mold	Saprolegniaceae	LE,RE
Leptolegnia subterranea	water mold	Saprolegniaceae	LE,RE
Protoachlya paradoxa	water mold	Saprolegniaceae	LE,RE
Saprolegnia diclina	water mold	Saprolegniaceae	LE,RE
Saprolegnia ferax	water mold	Saprolegniaceae	LE,RE
Saprolegnia monoica	water mold	Saprolegniaceae	LE,RE
Saprolegnia parasitica	water mold	Saprolegniaceae	LE,RE
Saprolegnia sp.	water mold	Saprolegniaceae	LE,RE
Order Leptomitales			
Apodachlya brachynema	water mold	Leptomitaceae	LE,RE
Order Lagenidales			
Olpidiopsis saprolegniae	water mold	Olpidiopsidaceae	LE,RE
Olpidiopsis varians	water mold	Olpidiopsidaceae	LE,RE
Order Peronosporales (downy mildews)			
Cystopus bliti	downy mildew	Peronosporaceae	RE
Cystopus candidus	downy mildew	Peronosporaceae	RE
Peronospora geranii	downy mildew	Peronosporaceae	RE
Peronospora parasitica	downy mildew	Peronosporaceae	RE
Phytophthora cactorum	crown rot	Pythiaceae	CK
Phytophthora undulatum	downy mildew	Pythiaceae	LE,RE
Plasmopara sordida	downy mildew	Peronosporaceae	RE
Plasmopara viticola	downy mildew of grape	Peronosporaceae	CK,ES,RE
Pythium aphanidermatum	downy mildew	Pythiaceae	LE,RE
Pythium cystosiphon?	downy mildew	Pythiaceae	LE,RE
Pythium debaryanum	downy mildew	Pythiaceae	LE,RE
Pythium proliferum	downy mildew	Pythiaceae	LE,RE
Pythium pulchrum	downy mildew	Pythiaceae	LE,RE
Pythium sp.	downy mildew	Pythiaceae	LE,RE
Pythium ultimum	downy mildew	Pythiaceae	LE,RE
CLASS ZYGOMYCETES (pair fungi)			
Order Entomophthorales			
Empusa grylli	mold	Entomophthoraceae	RE
Order Mucorales			
Mucor stolonifer	mold	Mucoraceae	RE
Rhizopus sp.	bread mold	Mucoraceae	CK
DIVISION ASCOMYCOTA (ascomycetes or bladder fungi)			
CLASS HEMIASCOMYCETES (yeasts)			
Order Protomycetales			
Taphrina communis	plum pockets	Protomycetaceae	CK
Taphrina deformans	peach leaf curl	Protomycetaceae	CK
CLASS LOCULOASCOMYCETES (rots & scabs)			
Order Myriangiales			
Elsinoë corni	dogwood anthracnose	Elsinoëaceae	CK
Order Dothideales			
Botryosphaeria dothidea	white apple rot	Dothioraceae	CK
Botryosphaeria obtusa	black apple rot	Dothioraceae	CK
dothidean spp.	pear sooty molds	Dothideaceae	CK
Mycosphaerella fragariae	strawberry leaf spot	Dothideaceae	CK
Plowrightia morbosa	rot	Dothideaceae	RE

Order Pleosporales	Common Name	Family	Location
Apiosporina morbosa	black knot	Venturiaceae	CK
Venturia crataegi	apple scab	Venturiaceae	CK
Venturia pyrina	pear scab	Venturiaceae	CK
CLASS PLECTOMYCETES (ascomolds)			
Order Eurotiales			
Aspergillus herbariorum	mold	Trichocomaceae	RE
Aspergillus niger	mold	Trichocomaceae	RE
Ophiostoma ulmi	Dutch elm disease	Ophiostomataceae	CK
Penicillium crustaceum	mold	Trichocomaceae	RE
Penicillium sp.	blue mold	Trichocomaceae	CK
CLASS PYRENOMYCETES (flask fungi)			
Order Erysiphales (powdery mildews)			
Erysiphe cichoracearum	powdery mildew	Erysiphaceae	RE
Erysiphe communis	powdery mildew	Erysiphaceae	RE
Erysiphe montagnei	powdery mildew	Erysiphaceae	RE
Erysiphe polygoni	black locust powdery mildew	Erysiphaceae	RE
Microsphæra alni	lilac powdery mildew	Erysiphaceae	CK,RE
Microsphæra diffusa	powdery mildew	Erysiphaceae	RE
Microsphæra ravenellii	powdery mildew	Erysiphaceae	RE
Microsphaera viburni	powdery mildew	Erysiphaceae	CK
Phyllactinia corylea	tree powdery mildew	Erysiphaceae	RE
Podosphaera leucotricha	apple powdery mildew	Erysiphaceae	CK
Podosphæra oxyacanthæ	powdery mildew	Erysiphaceae	RE
Sphærotheca castagnei	downy mildew	Erysiphaceae	RE
Uncinula necator	grape powdery mildew	Erysiphaceae	CK
Order Xylariales (flask fungi)			
Daldinia cingulata	zoned black fungus	Xylariaceae	RE
Hypoxylon sp.	wood-wart	Xylariaceae	RE
Xylaria digitata	finger fungus	Xylariaceae	RE
Xylaria polymorpha	dead man's fingers	Xylariaceae	RE
Order Diaporthales (flask fungi)			
Apiognomonia veneta	sycamore anthracnose	Diaporthaceae	CK
Cryphonectria parasitica	chestnut blight	Diaporthaceae	CK
Diaporthe ailanthi	flask fungus	Diaporthaceae	RE
Glomerella cingulata	apple bitter rot	Diaporthaceae	CK
Guignardia bidwellii	grape black rot	Diaporthaceae	CK,RE
Order Hypocreales			
Leucostoma sp.	peach canker	Hypocreaceae	CK
Nectria galligena	nectria canker	Hypocreaceae	CK
Order Clavicipitales (flask fungi)			
Claviceps purpurea	ergot claviceps	Clavicipitaceae	RE
Cordyceps militaris	military orange caterpillar fungus	Clavicipitaceae	RE
CLASS DISCOMYCETES (disc fungi)			
Order Phacidiales			
Rhytisma sp.	maple tar spot	Rhytismataceae	CK
Order Helotiales (earth tongues)			
Blumeriella jaapii	cherry leaf spot	Dermateaceae	CK
Monilinia fructicola	stone fruits brown rot	Sclerotiniaceae	CK
Pseudopeziza medicaginis	leaf spot	Dermateaceae	RE
Sclerotinia fructigena	rind rot	Sclerotiniaceae	ES
Order Pezizales (cup fungi and allies)			
Aleuria aurantia	orange peel fungus	Aleuriaceae	CK
Lachnea scutellata	patella	Pezizaceae	RE
Macropodia semitosta	paxina	Pezizaceae	RE

Order Pezizales (cont'd)	Common Name	Family	Location
Morchella esculenta	common morel	Morchellaceae	CK
Patella setosa	cup fungus	Pezizaceae	CK
DIVISION BASIDIOMYCOTA (basidomycetes or small base fungi)			
CLASS TELIOMYCETES (rust and smut fungi)			
Order Uredinales (rust fungi)			
Aecidium cimicifugatum	rust	Pucciniaceae	RE
Aecidium compositatum	rust	Pucciniaceae	RE
Aecidium fraxini	rust	Pucciniaceae	RE
Aecidium grossulariæ	rust	Pucciniaceae	RE
Aecidium impatientis	rust	Pucciniaceae	RE
Aecidium nesææ	rust	Pucciniaceae	RE
Aecidium oenotheræ	rust	Pucciniaceae	RE
Aecidium pammelii	rust	Pucciniaceae	RE
Aecidium pustulatum	rust	Pucciniaceae	RE
Allodus podophylli	May-apple rust	Pucciniaceae	CK
Coleosporium sonchi-arvensis	rust	Melampsoraceae	RE
Gymnoconia peckiana	rust	Pucciniaceae	RE
Gymnoconia sp.	orange rust	Pucciniaceae	CK
Gymnosporangium globosum	rust	Pucciniaceae	RE
Gymnosporangium juniperi-virginianae	cedar-apple rust	Pucciniaceae	CK
Gymnosporangium nidus-avis	rust	Pucciniaceae	RE
Kunkelia nitens	blackberry rust	Pucciniaceae	CK
Melampsora salicis-capreæ	melampsora rust	Melampsoraceae	RE
Negrido caladii	Jack in the pulpit rust	Pucciniaceae	CK
Phragmidium obtusum	rust	Pucciniaceae	RE
Puccinia caricis	current rust	Pucciniaceae	RE
Puccinia coronata	buckthorn crown rust	Pucciniaceae	RE
Puccinia fraxinata	rust	Pucciniaceae	RE
Puccinia glechomatis	rust	Pucciniaceae	RE
Puccinia graminis	grape rust	Pucciniaceae	RE
Puccinia helianthi	rust	Pucciniaceae	RE
Puccinia malvacearum	rust	Pucciniaceae	RE
Puccinia menthæ	rust	Pucciniaceae	RE
Puccinia osmorhizæ	rust	Pucciniaceae	RE
Puccinia podophylli	rust	Pucciniaceae	RE
Puccinia polygoni-amphibii	rust	Pucciniaceae	RE
Puccinia seymeriæ	rust	Pucciniaceae	RE
Puccinia simplex	rust	Pucciniaceae	RE
Puccinia taraxaci	rust	Pucciniaceae	RE
Puccinia xanthii	rust	Pucciniaceae	RE
Pucciniastrum agrimoniæ	rust	Pucciniastraceae	RE
Uromyces euphorbiæ	rust	Pucciniaceae	RE
Uromyces phaseoli	rust	Pucciniaceae	RE
Uromyces striatus	rust	Pucciniaceae	RE
Uromyces toxicodendri	rust	Pucciniaceae	RE
Uromyces trifolii	rust	Pucciniaceae	RE
Order Ustilaginales (smut fungi)			
Entyloma menispermi	smut	Tilletiaceae	RE
Ustilago avenæ	smut	Ustilaginaceae	RE
Ustilago hordei	smut	Ustilaginaceae	RE
Ustilago maydis	corn smut	Ustilaginaceae	CK
Ustilago zeæ	smut	Ustilaginaceae	CK,RE
CLASS PHRAGMOBASIDIOMYCETES (jelly and waxy fungi)			
Order Eutremellales (jelly fungi)			
Exidia spiculosa	jelly fungus	Tremellaceae	CK
Tremella candida	jelly fungus	Tremellaceae	RE

Order Metatremellales (waxy fungi)	Common Name	Family	Location
Calocera cornea	clublike tuning fork	Dacrymycetaceae	RE
CLASS HYMENOMYCETES (exposed hymenium fungi)			
Order Agaricales (coral and pore fungi)			
Agaricus campestris	meadow mushroom	Agaricaceae	CK
Agaricus comtulus	agaricus	Agaricaceae	RE
Amanita phalloides	death cup	Amanitaceae	RE
Amanitopsis vaginata	sheathed amanitopsis	Amanitaceae	RE
Armillaria mellea	honey mushroom	Agaricaceae	CK
Atrichum undulatum	wavy Catherinea mushroom	Polyporaceae	CK
Bjerkandera adusta	pore fungus	Polyporaceae	CK
Boletus chrysenteron	golden-flesh or red-crack bolete	Boletaceae	RE
Boletus piperatus	edible bolete	Boletaceae	RE
Clavaria flaccida	soft coral fungus	Clavariaceae	RE
Clavaria pyxidata	edible coral fungus	Clavariaceae	RE
Clavaria sp.	coral mushroom	Clavariaceae	CK
Clitocybe infundibuliformis-membranacea	funnel clitocybe	Tricholomataceae	RE
Clitopilus abortivus	field type mushroom	Agaricaceae	CK
Collybia delicatella	collybia	Tricholomataceae	RE
Collybia dryophila	oak-loving collybia	Tricholomataceae	RE
Collybia myriadophylla	conifer collybia	Tricholomataceae	RE
Collybia platyphylla	broad-gilled collybia	Tricholomataceae	RE
Coprinus fuscescens	ink-cup	Coprinaceae	RE
Coprinus micaceus	glistening ink-cup	Coprinaceae	RE
Crepidotus malachius	spotted stumpfoot	Agaricaceae	CK
Daedalea confragosa	currycomb bracket fungus	Polyporaceae	CK
Daedalea quercina	oak mazegill fungus	Polyporaceae	CK
Entoloma sp.	entoloma	Rhodophyllaceae	RE
Favolus alveolaris	pore fungus	Polyporaceae	CK
Fomes applanatus	artist's fomes	Polyporaceae	RE
Fomes everhartii	artist's type fungus	Polyporaceae	CK
Fomes ohioensis	artist's type fungus	Polyporaceae	CK
Galera sp.	deadly galerina	Cortinariaceae	RE
Ganoderma applanatum	artist's shelf fungus	Polyporaceae	CK
Gomphidius sp.	gomphidius	Gomphidiaceae	RE
Gyrodom merulioides	fleshy pore fungus or bolete	Boletaceae	CK
Hydrochaete olivacea	red leather fungus	Polyporaceae	CK,RE
Inocybe sp.	fiber cap	Cortinariaceae	RE
Irpex lacteus	white leather fungus	Polyporaceae	RE
Lactarius rimosellus	milk cap	Russulaceae	RE
Lactarius subdulcis	dull milk cap	Russulaceae	RE
Lactarius theiogalus	yellow -straining milk cap	Russulaceae	RE
Laetiporus sulphurous	sulfur polypore	Polyporaceae	RE
Lentinus sulcatus	lentinus	Tricholomataceae	RE
Lenzites betulina	birch mazegill fungus	Polyporaceae	CK
Lenzites sepiaria	gill polypore	Polyporaceae	RE
Lepiota adirondackensis	Adirondacks lepiota	Lepiotaceae	RE
Lepiota cristata	crested lepiota	Lepiotaceae	RE
Lepiota erminea	ermine lepiota	Lepiotaceae	RE
Lepiota illinita	lepiota	Lepiotaceae	RE
Macrolepiota procera	parasol mushroom	Lepiotaceae	CK
Marasmius albiceps	marasmius	Tricholomataceae	RE
Marasmius candidus	marasmius	Tricholomataceae	RE
Marasmius nigripes	marasmius	Tricholomataceae	RE
Marasmius oreades	fairy-ring mushroom	Tricholomataceae	CK
Marasmius siccus	orange pin-wheel	Tricholomataceae	RE
Marasmius trullisatipes	marasmius	Tricholomataceae	RE
Mycena capillaris	bonnet mushroom	Tricholomataceae	RE
Oligoporus tephroleucus	pore fungus	Polyporaceae	CK
Panus rudis	rudy panus	Amanitaceae	RE

Order Agaricales (cont'd)	**Common Name**	**Family**	**Location**
Panus strypticus	field type mushroom	Amanitaceae	CK
Phaeolus schweinitzii	polypore	Polyporaceae	RE
Phellinus gilvus	polypore	Polyporaceae	CK,RE
Pholiota unicolor	scalecap mushroom	Cortinariaceae	CK
Pleurotus sapidus	lavender-spored pleurotus	Tricholomataceae	CK,RE
Pluteus cervinus	fawn-colored pluteus	Vovlariaceae	RE
Polyporus arcularius	polypore	Polyporaceae	CK,RE
Polyporus carneus	polypore	Polyporaceae	RE
Polyporus elegans	pore fungus	Polyporaceae	CK
Polyporus squamosus	Dryad's saddle fungus	Polyporaceae	CK
Polystictus hirsutus-albiporus	polypore	Polyporaceae	RE
Poria unita	pore fungus	Polyporaceae	CK
Psilocybe ammophila	psilocybe	Cortinariaceae	RE
Pyenoporus cinnibarinus	cinnabar polypore	Polyporaceae	RE
Russula alutacea	red brittle gills	Russulaceae	RE
Russula compacta	compact brittle gills	Russulaceae	RE
Russula ftens	fetid brittle gills	Russulaceae	RE
Russula pectinata	brittle gills	Russulaceae	RE
Russula xerampelina	crab-scented brittle gills	Russulaceae	RE
Schizophyllum commune	spit-gilled bracket	Schizophyllaceae	RE
Steccherinum ochraceum	hydnum tooth fungus	Hydnaceae	CK
Stereum candidum	sereum	Corticiaceae	RE
Stereum disciforme	sereum	Corticiaceae	RE
Stereum fasciatum	sereum	Corticiaceae	RE
Stereum frustulosum	false turkeytail fungus	Corticiaceae	CK
Stereum versicolor	sereum	Corticiaceae	RE
Strobilomyces strobilaceus	old-man-of-the-woods	Boletaceae	RE
Trametes conchifer	pore fungus	Polyporaceae	CK
Trametes versicolor	turkeytail or pore fungus	Polyporaceae	CK
Tricholoma albo-flavidum	knight-cap	Tricholomataceae	RE
CLASS GASTEROMYCETES (stomach fungi)			
Order Phallales			
Mutinus caninus	dog stinkhorn	Phallaceae	CK
Order Lycoperdales (puffballs)			
Bovista pila	common puffball	Lycoperdaceae	CK
Calvatia gigantea	giant puffball	Lycoperdaceae	CK
Geaster hygrometricus	water measuring earthstar	Lycoperdaceae	RE
Lycoperdon perlatum	gem puffball	Lycoperdaceae	CK
Lycoperdon pusillum	mini puffball	Lycoperdaceae	CK,RE
Lycoperdon pyriforme	pear-shaped or stump puffball	Lycoperdaceae	CK,RE
Myriostoma coliformis	pepper box	Lycoperdaceae	RE
Order Tulostomatales (stalked puffballs)			
Tulostoma campestre	field tylostoma	Tulostomataceae	RE
Tulostoma fimbriatum	buried-stalk puffball	Tulostomataceae	RE
Order Sclerodermatales			
Scleroderma citrinum	common earth ball	Sclerodermataceae	CK
Order Nidulariales (bird's-nest fungi)			
Cyathus striatus	fluted bird's nest	Nidulariaceae	RE
DIVISION DEUTEROMYCOTA (second or imperfect fungi)			
CLASS HYPOMYCETES			
Order Hyphomycetales			
Botrytis cinerea	raspberry mold	Moniliaceae	CK
Cercospora chenopodii	imperfect fungus	Dematiaceae	RE
Cercospora clavata	imperfect fungus	Dematiaceae	RE
Cercospora helianthi	imperfect fungus	Dematiaceae	RE

Order Hyphomycetales(cont'd)	Common Name	Family	Location
Cercospora maianthemi	imperfect fungus	Dematiaceae	RE
Cercospora monoica	imperfect fungus	Dematiaceae	RE
Cercospora osmorhizæ	imperfect fungus	Dematiaceae	RE
Cercospora oxybaphi	imperfect fungus	Dematiaceae	RE
Cercospora tuberosa	imperfect fungus	Dematiaceae	RE
Cladosporium carpophilum	peach scab	Moniliaceae	CK
Didymaria ungeri	imperfect fungus	Moniliaceae	RE
Drechslera teres	imperfect fungus	Dematiaceae	RE
Macrosporium saponariæ	imperfect fungus	Dematiaceae	RE
Macrosporium solani	imperfect fungus	Dematiaceae	RE
Ovularia obliqua	imperfect fungus	Moniliaceae	RE
Ramularia arvensis	imperfect fungus	Moniliaceae	RE
Ramularia celastiri	imperfect fungus	Moniliaceae	RE
Ramularia variabilis	imperfect fungus	Moniliaceae	RE
Rhinotrichum curtisii	imperfect fungus	Moniliaceae	RE
Order Tuberculariales			
Tuberculina persicina	imperfect fungus	Tuberculariaceae	RE
CLASS COELOMYCETES			
Order Melanconiales			
Cylindrosporium padi	imperfect fungus	Melanconiaceae	RE
Gleosporium irregulare	imperfect fungus	Melanconiaceae	RE
Gleosporium nervisequum	imperfect fungus	Melanconiaceae	RE
Gleosporium septorioides	imperfect fungus	Melanconiaceae	RE
Marsonia toxicodendri	imperfect fungus	Melanconiaceae	RE
Order Sphaeropsidales			
Cicinnobolus cesatii	imperfect fungus	Sphaeropsidaceae	RE
Coniothyrium sp.	raspberry cane blight	Sphaeropsidaceae	CK
Diplodia maydis	corn ear rot	Sphaeropsidaceae	CK
Peltaster fructicola	apple sooty blotch mold	Leptostromataceae	CK
Phoma uvicola	imperfect fungus	Sphaeropsidaceae	RE
Phyllosticta cruenta	imperfect fungus	Sphaeropsidaceae	RE
Phyllosticta iridis	imperfect fungus	Sphaeropsidaceae	RE
Phyllosticta palustri	imperfect fungus	Sphaeropsidaceae	RE
Phyllosticta phaseolina	imperfect fungus	Sphaeropsidaceae	RE
Septoria ægopodii	imperfect fungus	Sphaeropsidaceae	RE
Septoria aquilegiæ	imperfect fungus	Sphaeropsidaceae	RE
Septoria erigerontis	imperfect fungus	Sphaeropsidaceae	RE
Septoria lactucicola	imperfect fungus	Sphaeropsidaceae	RE
Septoria littorea	imperfect fungus	Sphaeropsidaceae	RE
Septoria lophanthi	imperfect fungus	Sphaeropsidaceae	RE
Septoria musiva	imperfect fungus	Sphaeropsidaceae	RE
Septoria ochroleuca	imperfect fungus	Sphaeropsidaceae	RE
Septoria oenotheræ	imperfect fungus	Sphaeropsidaceae	RE
Septoria podophyllina	imperfect fungus	Sphaeropsidaceae	RE
Septoria polygonorum	imperfect fungus	Sphaeropsidaceae	RE
Septoria rubi	imperfect fungus	Sphaeropsidaceae	RE
Septoria scrophulariæ	imperfect fungus	Sphaeropsidaceae	RE
Septoria violæ-palustris	imperfect fungus	Sphaeropsidaceae	RE
Zygophiala jamaicensis	apple flyspeck	Leptostromataceae	CK
DIVISION MYCOPHYCOPHYTA (lichens or fungus algae)			
CLASS ASCOLICHENES (ascomycote lichens)			
Order Pyrenulales			
Arthopyrenia alba	lichen	Pyrenulaceae	RE
Microthelia micula	lichen	Pyrenulaceae	RE
Pyrenula leucoplaca	lichen	Pyrenulaceae	RE
Trypethelium virens	lichen	Trypetheliaceae	RE
Verrucaria muralis	pitted lichen	Verrucariaceae	RE

Order Caliciales	Common Name	Family	Location
Coniocybe furfuracea	lichen	Caliciaceae	RE
Order Hysteriales			
Arthonia punctiformis	lichen	Arthoniaceae	RE
Arthonia radiata	lichen	Arthoniaceae	RE
Arthothelium spectabile	lichen	Arthoniaceae	RE
Graphis scripta	script lichen	Graphidaceae	RE
Opegrapha lichenoides	lichen	Graphidaceae	RE
Opegrapha pulicaris	lichen	Graphidaceae	RE
Opegrapha viridis	lichen	Graphidaceae	RE
Order Lecanorales			
Alectoria nidulifera	lichen	Usneaceae	RE
Anaptychia echinata	lichen	Physciaceae	RE
Anaptychia hypoleuca	lichen	Physciaceae	RE
Anaptychia leucomelaena	lichen	Physciaceae	RE
Anaptychia palmulata	lichen	Physciaceae	RE
Anaptychia speciosa	lichen	Physciaceae	RE
Bacidia fuscorubella	lichen	Lecideaceae	RE
Bacidia schweinitzii	lichen	Lecideaceae	RE
Bilimbia sabuletorum	lichen	Lecideaceae	RE
Bilimbia trachona	lichen	Lecideaceae	RE
Buellia parasema	lichen	Buelliaceae	RE
Caloplaca aurantiaca	lichen	Caloplacaceae	RE
Caloplaca cerina	lichen	Caloplacaceae	RE
Candelaria concolor	lichen	Parmeliaceae	RE
Candelaria fibrosa	lichen	Parmeliaceae	RE
Cetraria ciliaris	shield lichen	Parmeliaceae	RE
Cetraria ericetorum	shield lichen	Parmeliaceae	RE
Cladonia arbuscula	lichen	Cladoniaceae	RE
Cladonia bacillaris	lichen	Cladoniaceae	RE
Cladonia caespiticia	lichen	Cladoniaceae	RE
Cladonia capitata	lichen	Cladoniaceae	RE
Cladonia coniocraea	lichen	Cladoniaceae	RE
Cladonia conista	lichen	Cladoniaceae	RE
Cladonia cristatella	British soldiers or red crest lichen	Cladoniaceae	RE
Cladonia cryptochlorophaea	lichen	Cladoniaceae	RE
Cladonia fimbriata	lichen	Cladoniaceae	RE
Cladonia furcata	lichen	Cladoniaceae	RE
Cladonia gracilis	spoon lichen	Cladoniaceae	RE
Cladonia grayi	lichen	Cladoniaceae	RE
Cladonia nemoxyna	lichen	Cladoniaceae	RE
Cladonia parasitica	lichen	Cladoniaceae	RE
Cladonia pyxidata	pixie cup lichen	Cladoniaceae	RE
Cladonia rangiferina	reindeer lichen	Cladoniaceae	RE
Cladonia sp.	reindeer moss	Cladoniaceae	CK
Cladonia squamosa	lichen	Cladoniaceae	RE
Cladonia subcariosa	lichen	Cladoniaceae	RE
Cladonia verticillata	ladder lichen	Cladoniaceae	RE
Collema subfurvum	lichen	Collemaceae	RE
Conotrema urceolatum	lichen	Diploschistaceae	RE
Lecanora dispersa	lichen	Lecanoraceae	RE
Lecanora pallida	lichen	Lecanoraceae	RE
Lecanora subfusca	lichen	Lecanoraceae	RE
Lecanora varia	lichen	Lecanoraceae	RE
Lecidea albocaerulescens	whitewash lichen	Lecideaceae	RE
Lecidea myriocarpoides	whitewash lichen	Lecideaceae	RE
Lecidea parasema	whitewash lichen	Lecideaceae	RE
Lecidea viridescens	whitewash lichen	Lecideaceae	RE
Lepraria sp.	lichen	Leprariaceae	RE

Order Lecanorales (cont'd)	Common Name	Family	Location
Leptogium lichenoides	lichen	Collemaceae	RE
Leptogium tenuissimum	lichen	Collemaceae	RE
Leptogium tremelloides	lichen	Collemaceae	RE
Ochrolechia tartarea	lichen	Lecanoraceae	RE
Parmelia aspera	boulder lichen	Parmeliaceae	RE
Parmelia aurulenta	boulder lichen	Parmeliaceae	RE
Parmelia borreri	boulder lichen	Parmeliaceae	RE
Parmelia caperata	boulder lichen	Parmeliaceae	RE
Parmelia crozalsiana	boulder lichen	Parmeliaceae	RE
Parmelia flaventior	boulder lichen	Parmeliaceae	RE
Parmelia livida	boulder lichen	Parmeliaceae	RE
Parmelia margaritata	boulder lichen	Parmeliaceae	RE
Parmelia perlata	boulder lichen	Parmeliaceae	RE
Parmelia rudecta	boulder lichen	Parmeliaceae	RE
Parmelia saxatilis	boulder lichen	Parmeliaceae	RE
Parmelia sulcata	boulder lichen	Parmeliaceae	RE
Parmelia ulophyllodes	boulder lichen	Parmeliaceae	RE
Peltigera aphthosa	lichen	Peltigeraceae	RE
Peltigera canina	dog lichen	Peltigeraceae	RE
Peltigera canina spuria	lichen	Peltigeraceae	RE
Peltigera horizontalis	lichen	Peltigeraceae	RE
Peltigera spuria	lichen	Peltigeraceae	RE
Pertusaria leioplaca	lichen	Pertusariaceae	RE
Pertusaria multipuncta	lichen	Pertusariaceae	RE
Pertusaria pertusa	lichen	Pertusariaceae	RE
Pertusaria pustulata	lichen	Pertusariaceae	RE
Physcia adscendens	lichen	Physciaceae	RE
Physcia aguila detonsa	lichen	Physciaceae	RE
Physcia aipolia	lichen	Physciaceae	RE
Physcia ciliata	lichen	Physciaceae	RE
Physcia elaeina	lichen	Physciaceae	RE
Physcia grisea	lichen	Physciaceae	RE
Physcia hypoleuca	lichen	Physciaceae	RE
Physcia millegrana	lichen	Physciaceae	RE
Physcia orbicularis	lichen	Physciaceae	RE
Physcia stellaris	lichen	Physciaceae	RE
Physcia syncolla	lichen	Physciaceae	RE
Physcia tribacia	lichen	Physciaceae	RE
Physcia tribacoides	lichen	Physciaceae	RE
Placynthium nigrum	lichen	Pannariaceae	RE
Ramalina farinacea	lichen	Usneaceae	RE
Ramalina sinensis	lichen	Usneaceae	RE
Rinodina tephraspis	lichen	Buelliaceae	RE
Sarcogyne simplex	lichen	Acarosporaceae	RE
Sticta pulmonaria	lichen	Stictaceae	RE
Teloschistes chrysophthalmus	lichen	Teloschistaceae	RE
Usnea strigosa	lichen	Usneaceae	RE
Xanthoria candelaria	lichen	Teloschistaceae	RE
Xanthoria fallax	lichen	Teloschistaceae	RE
Xanthoria polycarpa	lichen	Teloschistaceae	RE

KINGDOM PLANTAE

DIVISION BRYOPHYTA (mosses and liverworts)

	Common Name	Family	Location
CLASS HEPATICOPSIDA (liverworts)			
Order Jungermanniales			
Lophocolea heterophylla	liverwort	Lophocoleaceae	CK
Order Marchantiales (typical liverworts)			
Conocephalum conicum	common liverwort	Conocephalaceae	CK
Riccia fluitans	slender riccia	Ricciaceae	ES
Ricciocarpus natans	purple-fringed riccia	Ricciaceae	ES
CLASS SPHAGNOPSIDA (peat mosses)			
Order Sphagnales			
Sphagnum compactum	sphagnum	Sphagnaceae	RE
Sphagnum lescurii	sphagnum	Sphagnaceae	RE
Sphagnum magellanicum	sphagnum	Sphagnaceae	RE
Sphagnum palustre	boat-leaved sphagnum	Sphagnaceae	RE
Sphagnum russowii	sphagnum	Sphagnaceae	RE
Sphagnum sp.	bog moss	Sphagnaceae	CK
CLASS BRYOPSIDA (mosses)			
Order Polytrichales			
Atrichum altecristatum	spineleaf moss	Polytrichaceae	RE
Atrichum angustatum	slender Catherinea	Polytrichaceae	RE
Atrichum undulatum	spineleaf moss	Polytrichaceae	RE
Pogonatum pensilvanicum	false hair-cap moss	Polytrichaceae	RE
Polytrichum commune	common hair-cap moss	Polytrichaceae	CK,RE
Polytrichum ohioense	hair-cap moss	Polytrichaceae	CK,RE
Polytrichum piliferum	hair-cap moss	Polytrichaceae	RE
Order Tetraphales			
Tetraphis pellucida	four-tooth moss	Tetraphidaceae	RE
Order Funariales			
Discelium nudum	moss	Disceliaceae	RE
Funaria hygrometrica	cord moss	Funariaceae	CK,RE
Physcomitrium pyriforme	urn moss	Funariaceae	RE
Order Orthotrichales			
Drummondia prorepens	moss	Orthotrichaceae	RE
Orthotrichum anomalum	moss	Orthotrichaceae	RE
Orthotrichum pumilum	moss	Orthotrichaceae	RE
Orthotrichum pusillum	moss	Orthotrichaceae	RE
Orthotrichum strangulatum	moss	Orthotrichaceae	RE
Ulota crispa	moss	Orthotrichaceae	RE
Order Bryales			
Aulacomnium heterostichum	moss	Aulacomniaceae	RE
Aulacomnium palustre	moss	Aulacomniaceae	RE
Bartramia pomiformis	apple moss	Bartramiaceae	RE
Bryum argenteum	silvery moss	Bryaceae	RE
Bryum caespiticium	silvery moss	Bryaceae	RE
Bryum capillare	silvery moss	Bryaceae	RE
Bryum lisae var. *cuspidatum*	silvery moss	Bryaceae	RE
Bryum pseudotriquetrum	silvery moss	Bryaceae	RE
Leptobryum pyriforme	moss	Bryaceae	RE
Mnium cuspidatum	woodsy mnium moss	Mniaceae	CK
Mnium stellare	star moss	Mniaceae	RE
Philonotis fontana	moss	Bartramiaceae	RE
Plagiomnium ciliare	moss	Mniaceae	RE
Plagiomnium cuspidatum	moss	Mniaceae	RE
Plagiomnium medium	moss	Mniaceae	RE
Pohlia nutans	moss	Bryaceae	RE

Order Bryales (cont'd)	Common Name	Family	Location
Rhizomnium punctatum	moss	Mniaceae	RE
Rhodobryum roseum	rose moss	Bryaceae	RE
Order Hypnobryales			
Amblystegium serpens	moss	Amblystegiaceae	RE
Amblystegium serpens var. *juratzkanum*	moss	Amblystegiaceae	RE
Amblystegium varium	moss	Amblystegiaceae	CK,RE
Brachythecium acuminatum	moss	Brachytheciaceae	RE
Brachythecium campestre	moss	Brachytheciaceae	RE
Brachythecium oxycladon	moss	Brachytheciaceae	RE
Brachythecium rivulare	rivulet brachythecium	Brachytheciaceae	RE
Brachythecium rutabulum	moss	Brachytheciaceae	RE
Brachythecium salebrosum	moss	Brachytheciaceae	RE
Bryhnia graminicolor	moss	Brachytheciaceae	RE
Bryhnia novae-angliae	moss	Brachytheciaceae	RE
Bryoandersonia illecebra	moss	Brachytheciaceae	RE
Callicladium haldanianum	moss	Hypnaceae	RE
Calliergon stramineum	moss	Amblystegiaceae	RE
Calliergon trifarium	moss	Amblystegiaceae	RE
Calliergonella cuspidata	moss	Amblystegiaceae	RE
Campylium chrysophyllum	moss	Amblystegiaceae	RE
Campylium hispidulum	moss	Amblystegiaceae	RE
Campylium polygamum	moss	Amblystegiaceae	RE
Campylium stellatum	moss	Amblystegiaceae	RE
Cyrto-hypnum minutulum	moss	Thuidiaceae	RE
Drepanocladus aduncus var. *aduncus*	moss	Amblystegiaceae	RE
Drepanocladus aduncus var. *kneiffii*	moss	Amblystegiaceae	RE
Entodon cladorrhizans	moss	Entodontaceae	RE
Entodon seductrix	moss	Entodontaceae	RE
Eurhynchium hians	moss	Brachytheciaceae	RE
Eurhynchium pulchellum	moss	Brachytheciaceae	RE
Eurhynchium serrulatum	moss	Brachytheciaceae	CK
Helodium blandowii	moss	Thuidiaceae	RE
Helodium paludosum	moss	Thuidiaceae	RE
Herzogiella turfacea	moss	Hypnaceae	RE
Homomallium adnatum	moss	Hypnaceae	RE
Hygroamblystegium fluviatile	moss	Amblystegiaceae	RE
Hygroamblystegium tenax	moss	Amblystegiaceae	RE
Hygrohypnum luridum	moss	Amblystegiaceae	RE
Hypnum cupressiforme	moss	Hypnaceae	RE
Hypnum curvifolium	feather moss	Hypnaceae	CK,RE
Hypnum imponens	moss	Hypnaceae	RE
Hypnum lindbergii	moss	Hypnaceae	RE
Isopterygiopsis muelleriana	moss	Hypnaceae	RE
Leptodictyum humile	moss	Amblystegiaceae	RE
Leptodictyum riparium	moss	Amblystegiaceae	RE
Limprichtia revolvens	moss	Amblystegiaceae	RE
Plagiothecium cavifolium	slender moss	Plagiotheciaceae	RE
Plagiothecium denticulatum	slender moss	Plagiotheciaceae	RE
Plagiothecium sp.	moss	Plagiotheciaceae	CK
Platydictya confervoides	moss	Hypnaceae	RE
Platygyrium repens	moss	Hypnaceae	RE
Pleurozium schreberi	moss	Hylocomiaceae	RE
Pylaisiella intricata	moss	Hypnaceae	RE
Pylaisiella selwynii	moss	Hypnaceae	RE
Rauiella scita	moss	Thuidiaceae	RE
Rhytidium rugosum	moss	Rhytidiaceae	RE
Sematophyllum demissum	moss	Sematophyllaceae	RE
Steerecleus serrulatus	moss	Brachytheciaceae	RE
Taxiphyllum taxirameum	moss	Hypnaceae	RE

Order Hypnobryales (cont'd)	Common Name	Family	Location
Thuidium delicatulum	common fern moss	Thuidiaceae	CK,RE
Thuidium recognitum	fern moss	Thuidiaceae	RE
Order Isobryales			
Anacamptodon splachnoides	moss	Fabroniaceae	RE
Anomodon attenuatus	moss	Leskeaceae	RE
Anomodon minor	moss	Leskeaceae	RE
Anomodon rostratus	moss	Leskeaceae	RE
Anomodon rugelii	moss	Leskeaceae	RE
Climacium americanum	tree moss	Climaciaceae	CK,RE
Climacium kindbergii	tree-flooded moss	Climaciaceae	CK,RE
Fontinalis dalecarlica	common water moss	Fontinaliaceae	RE
Fontinalis hypnoides	water moss	Fontinaliaceae	RE
Fontinalis hypnoides var. *duriaei*	water moss	Fontinaliaceae	RE
Hedwigia ciliata	white-tipped moss	Hedwigiaceae	RE
Leskea gracilescens	moss	Leskeaceae	RE
Leskea obscura	moss	Leskeaceae	RE
Leucodon julaceus	moss	Leucodontaceae	RE
Thelia asprella	moss	Leskeaceae	RE
Thelia hirtella	moss	Leskeaceae	RE
Order Pottiales			
Barbula convoluta	moss	Pottiaceae	RE
Barbula indica var. *indica*	twisted teeth moss	Pottiaceae	RE
Barbula unguiculata	moss	Pottiaceae	RE
Bryoerythrophyllum recurvirostre	moss	Pottiaceae	RE
Desmatodon obtusifolius	moss	Pottiaceae	RE
Desmatodon porteri	moss	Pottiaceae	RE
Didymodon fallax	moss	Pottiaceae	RE
Didymodon rigidulus	moss	Pottiaceae	RE
Gymnostomum aeruginosum	moss	Pottiaceae	RE
Hymenostylium recurvirostre	moss	Pottiaceae	RE
Hyophila involuta	moss	Pottiaceae	RE
Phascum cuspidatum	moss	Pottiaceae	RE
Tortella humilis	twisted moss	Pottiaceae	RE
Tortella tortuosa	twisted moss	Pottiaceae	RE
Tortula ruralis	wall moss	Pottiaceae	RE
Weissia controversa	moss	Pottiaceae	RE
Order Dicranales			
Bruchia flexuosa	moss	Ditrichaceae	RE
Ceratodon purpureus	purple horn-tooth moss	Ditrichaceae	RE
Dicranella cerviculata	fork moss	Dicranaceae	RE
Dicranella heteromalla	silky fork moss	Dicranaceae	RE
Dicranella varia	fork moss	Dicranaceae	RE
Dicranum flagellare	broom moss	Dicranaceae	RE
Dicranum scoparium	broom moss	Dicranaceae	RE
Dicranum viride	broom moss	Dicranaceae	RE
Ditrichum lineare	moss	Ditrichaceae	RE
Leucobryum glaucum	white pin-cushion moss	Leucobryaceae	RE
Pleuridium subulatum	moss	Ditrichaceae	RE
Order Fissidentales			
Fissidens adianthoides	moss	Fissidentaceae	RE
Fissidens bryoides	moss	Fissidentaceae	RE
Fissidens obtusifolius	moss	Fissidentaceae	RE
Fissidens taxifolius	moss	Fissidentaceae	CK,RE
Order Seligeriales			
Seligeria calcarea	moss	Seligeriaceae	RE
Seligeria campylopoda	moss	Seligeriaceae	RE
Seligeria pusilla	moss	Seligeriaceae	RE

Order Grimmiales	Common Name	Family	Location
Grimmia pulvinata	moss	Grimmiaceae	RE
Schistidium apocarpum	moss	Grimmiaceae	RE
Schistidium rivulare	moss	Grimmiaceae	RE
DIVISION LYCOPODIOPHYTA (clubmosses)			
CLASS LYCOPODIOPSIDA (clubmosses)			
Order Lycopodiales			
Lycopodium dendroideum	tree-like clubmoss	Lycopodiaceae	CK
Lycopodium obscurum	tree clubmoss	Lycopodiaceae	CK
DIVISION EQUISETOPHYTA (horsetails and scouring rushes)			
CLASS EQUISETOPSIDA (horsetails)			
Order Equisetales			
Equisetum arvense	field or common horsetail	Equisetaceae	CK,ES
Equisetum hyemale	rough horsetail, scouring rush	Equisetaceae	CK
DIVISION FILICOPHYTA [=POLYPODIOPHYTA] (ferns)			
CLASS FILICOPSIDA [=POLYPODIOPSIDA] (ferns)			
Order Ophioglossales			
Botrychium dissectum	cut-leaf grapefern	Ophioglossaceae	CK
Botrychium rugulosum	leathery grapefern	Ophioglossaceae	CK
Botrychium virginianum	rattlesnake fern	Ophioglossaceae	CK,ES
Order Polypodiales			
Adiantum pedatum	northern maidenhair fern	Adiantaceae	CK,ES
Athyrium filix-femina	subarctic lady fern	Aspleniaceae	CK,ES
Cystopteris bulbifera	bulblet fern	Aspleniaceae	CK
Cystopteris tenuis	fragile fern	Aspleniaceae	CK
Dryopteris carthusiana	spinulose woodfern	Aspleniaceae	CK,ES
Dryopteris intermedia	evergreen woodfern	Aspleniaceae	CK
Dryopteris marginalis	marginal shield-fern or woodfern	Aspleniaceae	CK
Dryopteris sp.	woodfern	Aspleniaceae	ES
Gymnocarpium dryopteris	oak-fern	Aspleniaceae	CK
Onoclea sensibilis	sensitive fern	Onocleaceae	CK,ES
Osmunda cinnamomea	cinnamon fern	Osmundaceae	ES
Osmunda claytoniana	fern	Osmundaceae	CK,ES
Phegopteris hexagonoptera	broad beech-fern	Aspleniaceae	CK
Polypodium virginianum	common polypody	Polypodiaceae	CK
Polystichum acrostichoides	Christmas fern	Aspleniaceae	CK,ES

Location Codes:
- CK – Old Woman Creek watershed upstream of the estuary
- ES – Old Woman Creek estuary (including watershed within boundaries of NERR)
- LE – Lake Erie, principally nearshore waters of Erie County and western Lorain County, Ohio
- RE – Regional occurrence, principally Lake Erie watersheds of eastern Erie County and western Lorain County, Ohio

APPENDIX B. VASCULAR PLANTS OF OLD WOMAN CREEK ESTUARY AND WATERSHED

LIVERWORTS (Ricciaceae)	Common Name	Phenology	Origin	Loc
Riccia fluitans	slender riccia		N	E
Ricciocarpus natans	purple-fringed riccia		N	E
CLUBMOSSES (Lycopodiaceae)				
Lycopodium dendroideum	tree-like clubmoss		N	W
Lycopodium obscurum	tree clubmoss	Jul-Nov	N	W
HORSETAILS (Equisetaceae)				
Equisetum arvense	field or common horsetail	Apr-Jul	N	E,W
Equisetum hyemale	rough horsetail, scouring rush	Jun-Aug	N	W
ADDER'S TONGUES (Ophioglossaceae)				
Botrychium dissectum	cut-leaf grapefern	Aug-Nov	N	W
Botrychium rugulosum [= *B. ternatum*]	leathery grapefern		N	W
Botrychium virginianum	rattlesnake fern	spring - eary summer	N	E,W
ROYAL FERNS (Osmundaceae)				
Osmunda cinnamomea	cinnamon fern	Apr-May	N	E
Osmunda claytoniana	interrupted fern	Mar-Jun	N	E,W
POLYPODIES (Polypodiaceae)				
Polypodium virginianum [= *P. vulgare*]	common polypody	Jul-Aug	N	W
MAIDENHAIR FERNS (Adiantaceae)				
Adiantum pedatum	northern maidenhair fern	Jun-Sep	N	E,W
SPLEENWORTS (Aspleniaceae)				
Athyrium filix-femina	subarctic lady fern	Aug-Sep	N	E,W
Cystopteris bulbifera	bulblet fern	Jun-Sep	N	W
Cystopteris tenuis	fragile fern		N	W
Dryopteris carthusiana [= *D. austriaca* var. *spinulosa*]	spinulose woodfern		N	E,W
Dryopteris carthusiana [=*D. austriaca* var. *spinulosa*]	spinulose woodfern		N	E,W
Dryopteris intermedia [= *D. austriaca* var. *intermedia*]	evergreen woodfern		N	W
Dryopteris marginalis	marginal shield-fern or woodfern	Jun-Oct	N	W
Dryopteris sp.	woodfern			E
Polystichum acrostichoides	Christmas fern	Jun-Oct	N	E,W
Gymnocarpium dryopteris	oak-fern		N(T)	W
Phegopteris hexagonoptera	broad beech-fern		N	W
Polystichum acrostichoides	Christmas fern	Jun-Oct	N	E,W
SENSITIVE FERNS (Onocleaceae)				
Onoclea sensibilis	sensitive fern	Jun-Oct	N	E,W
PINES (Pinaceae)				
Picea pungens	blue spruce	May	A	E
Pinus nigra	Austrian pine	May-Jun	A	E
Pinus rigida	pitch pine	May-Jun	N	E
Pinus strobus	eastern white pine	May-Jun	N	E
Pinus sylvestris	Scotch pine	May-Jun	A	E
Tsuga canadensis	eastern hemlock	May-Jun	N	E,W
BALD CYPRESSES (Taxodiaceae)				
Metasequoia glyptostroboides	dawn redwood	Apr-May	A	E

	Common Name	Phenology	Origin	Loc
CYPRESSES (Cupressaceae)				
Juniperus virginiana	eastern red cedar	May	N	W
MAGNOLIAS (Magnoliaceae)				
Liriodendron tulipifera	tulip tree, tulip-poplar	May-Jun	N	E,W
CUSTARD-APPLES (Annonaceae)				
Asimina triloba	common or North American papaw	Apr-May	N	W
LAURELS (Lauraceae)				
Lindera benzoin	northern spicebush	Mar-May	N	E,W
Sassafras albidum	sassafras	Apr-May	N	E,W
LIZARD'S TAILS (Saururaceae)				
Saururus cernuus	lizard's tail	Jun-Aug	N	E,W
BIRTHWORTS (Aristolochiaceae)				
Aristolochia serpentaria	Virginia snakeroot	May-Jul	N	W
Asarum canadense [= *A. reflexum*]	wild or short-lobed ginger	Apr-May	N	E,W
LOTUS-LILIES (Nelumbonaceae)				
Nelumbo lutea [= *Nelumbium luteum*]	American or water lotus, lotus-lily	Jul-Sep	N	E
WATER-LILIES (Nymphaeaceae)				
Nuphar lutea ssp. *advena*] [= *N. advena*	yellow cow-lily, spatterdock	Jun-Aug	N	E
Nymphaea odorata [= *N. tuberosa*]	white water-lily	Jun-Sep	N	E
HORNWORTS (Ceratophyllaceae)				
Ceratophyllum demersum	common hornwort, coontail	Jul-Sep	N	E
BUTTERCUPS (Ranunculaceae)				
Actaea pachypoda	white baneberry	May-Jun	N W	
Actaea rubra [= *A. spicata* ssp. *rubra*]	red baneberry	May-Jun	N(T)	W
Anemone canadensis	Canada thimble-weed	May-Aug	N	E,W
Anemone cylindrica	long-headed anemone	May-Jun	N(T)	W
Anemone quinquefolia	American woodland thimble-weed	Apr-Jun	N	E
Anemone virginiana	tall thimble-weed, windflower	Jun-Aug	N	E,W
Aquilegia canadensis	wild columbine	Apr-Jun	N	W
Caltha palustris	common marsh marigold	Apr - May	N	E,W
Cimicifuga racemosa	black snakeroot or cohosh	Jun-Sep	N	E,W
Clematis virginiana	Virginia virgin's-bower	Jul-Aug	N	E,W
Hepatica noblis var. *acuta* [= *H. acutiloba*]	sharp-lobed hepatica	Mar-Apr	N	E,W
Hydrastis canadensis	goldenseal	May-Jun	N	E,W
Ranunculus abortivus	subalpine or kidney buttercup	Apr-Jun	N	E,W
Ranunculus acris	tall or meadow buttercup	May-Sep	A	W
Ranunculus fascicularis	early buttercup	Apr-May	N(P)	E,W
Ranunculus flabellaris	yellow water buttercup	Apr-May	N	E
Ranunculus hispidus var. *caricetorurm*	bristly or hispid buttercup	Apr-May	N	E,W
Ranunculus hispidus var. *nitidus* [= *R. septentrionalis*]	northern swamp buttercup	Mar-May	N	E,W
Ranunculus pensylvanicus	Pennsylvania buttercup	Jul-Aug	N	E
Ranunculus recurvatus	hooked buttercup or crowfoot	Apr-Jun	N	E,W
Ranunculus repens	creeping buttercup	May-Jul	A	E
Ranunculus sceleratus	celery-leaf buttercup	Jun-Sep	N	E,W
Thalictrum dioicum	early meadow-rue	May	N	E,W
Thalictrum pubescens [= *T. polygamum*]	tall meadow-rue	Jul-Sep	N	W
Thalictrum thalictroides [= *Anemonella thalictroides*]	rue anemone	Mar-May	N	E

BARBERRIES (Berberidaceae)	Common Name	Phenology	Origin	Loc
Berberis thunbergii	Japanese barberry	May	A	E,W
Berberis vulgaris	European or common barberry	May-Jun	A	E
Caulophyllum thalictroides	blue cohosh	Apr-Jun	N	W
Podophyllum peltatum	may-apple	Apr-May	N	E,W
MOONSEEDS (Menispermaceae)				
Menispermum canadense	Canada moonseed	Jun-Jul	N	E,W
POPPIES (Papaveraceae)				
Chelidonium majus	celandine	Apr-Aug	A	W
Sanguinaria canadensis	bloodroot	Mar-May	N	E,W
FUMITORIES (Fumariaceae)				
Dicentra canadensis	squirrel-corn	Apr-May	N	W
Dicentra cucullaria	Dutchman’s breeches	Apr-May	N	E,W
Fumaria officinalis	fumitory	May-Aug	A	W
PLANE-TREES (Platanaceae)				
Platanus occidentalis	American sycamore	Apr-Jun	N	E,W
WITCH HAZELS (Hamamelidaceae)				
Hamamelis virginiana	American witch hazel	Sep-Nov	N	W
ELMS (Ulmaceae)				
Celtis occidentalis	common or northern hackberry	Oct-Nov	N	E,W
Ulmus americana	American or white elm	Mar-May	N	E,W
Ulmus pumila	Siberian elm	Apr-May	A	W
Ulmus rubra	slippery or red elm	Mar-Apr	N	E,W
MULBERRIES (Moraceae)				
Maclura pomifera	osage-orange	May-Jun	Z	W
Morus alba	white mulberry	May-Jun	C	E,W
Morus rubra	red mulberry	Jun-Jul	N	W
NETTLES (Urticaceae)				
Boehmeria cylindrica	small-spike false-nettle	Jul-Aug	N	E
Laportea canadensis	Canada wood-nettle	Jul-Aug	N	E
Parietaria pensylvanica	Pennsylvania pellitory	May-Sep	N	W
Pilea fontana	springs clearweed	Jul-Sep	N	E
Pilea pumila	Canada clearweed	Jul-Sep	N	E,W
Urtica dioica	stinging nettle	Jul-Aug	A	E,W
Urtica dioica ssp. *gracilis* [= *U. gracilis*; *U. procera*]	slender or tall nettle	Jul-Sep	A	E,W
WALNUTS (Juglandaceae)				
Carya alba [= *C. tomentosa*]	mockernut hickory	May-Jun	N	E
Carya cordiformis	bitter-nut hickory	May	N	E,W
Carya ovata	shag-bark hickory	May	N	E,W
Juglans cinerea	butternut	May	N(P)	W
Juglans nigra	black walnut	Apr-May	N	E,W
BEECHES (Fagaceae)				
Castanea dentata	American chestnut	Jun-Aug	N(P)	E,W
Fagus grandifolia [= *F. ferrunginea*]	American beech	Apr-May	N	E,W
Quercus alba	white oak	May-Jun	N	E,W
Quercus bicolor	swamp white oak	May	N	E,W
Quercus coccinea	scarlet oak	May	N	E,W
Quercus macrocarpa	bur oak	May	N	E,W
Quercus nigra	water or black oak	May	N	E
Quercus palustris	pin oak	May-Jun	N	E,W
Quercus rubra var. *ambigua* [= *Q. borealis*]	northern red oak	May-Jun	N	E,W
Quercus velutina	black oak	May	N	E,W

BIRCHES & HAZELS (Betulaceae)	**Common Name**	**Phenology**	**Origin**	**Loc**
Alnus serrulata	brook-side or smooth alder	Mar-Apr	N	E
Carpinus carolinana	American hornbeam, ironwood	Apr	N	W
Corylus americana	American hazel-nut	Mar-Apr	N	E,W
Ostrya virginiana	eastern hop-hornbeam	Apr-May	N	E,W
POKEWEEDS (Phytolaccaceae)				
Phytolacca americana	common pokeweed	Jun-Sep	N	E,W
FOUR-O'CLOCKS (Nyctaginaceae)				
Mirabilis nyctaginea	heart-leaf or wild four-o'clock	Sep	N	E
GOOSEFOOTS & PIGWEEDS (Chenopodiaceae)				
Atriplex sp.	orache	Jun-Nov		W
Chenopodium album	white goosefoot, lamb's quarters	Sep	A	E,W
Chenopodium simplex [= *C. hybridum*]	maple-leaved goosefoot	Jun-Oct	N	W
Cycloloma atriplicifolium	winged pigweed	Sep	N	E
Salsola kali	Russian thistle, saltwort	Aug-Sep	A	E
AMARANTHS (Amaranthaceae)				
Amaranthus albus	white amaranth, tumbleweed	Sep	N	E
Amaranthus retroflexus	red-root amaranth, pigweed	Aug-Sep	N	E
Amaranthus tuberculatus	rough-fruit amaranth	Aug-Oct	N	E
Amaranthus sp.	pigweed	Aug-Oct		W
PURSLANES (Portulacaceae)				
Claytonia virginica	narrow-leaf spring-beauty	early spring	N	E,W
Portulaca oleracea	common purslane	Jun-Sep	A	E,W
CARPET-WEEDS (Molluginaceae)				
Mollugo verticillata	green carpet-weed	Jun-Nov	Z	W
PINKS (Caryophyllaceae)				
Arenaria serpyllifolia	thyme-leaf sandwort	Apr-Aug	A	W
Cerastium arvense	field chickweed	Apr-Aug	N	E
Cerastium fontanum	mouse-ear chickweed	Apr-Oct	A	E
Cerastium fontanum ssp. *vulgare* [= *C. vulgatum*]	common mouse-ear chickweed	Apr-Oct	A	E,W
Dianthus armeria	Deptford pink	May-Jul	A	W
Saponaria officinalis	bouncing-bet	Jun-Sep	A	E,W
Silene antirrhina	sleepy catchfly	May-Sep	N	W
Silene latifolia ssp. *alba* [= *S. pratensis*]	white campion	Apr-Aug	A	W
Stellaria graminea	lesser starwort or stitchwort	May-Oct	A	W
Stellaria longifolia	long-leaf starwort or stitchwort	May-Jul	N	W
Stellaria media	common chickweed	Feb-Dec	A	W
Stellaria pubera	great chickweed	Apr-Jun	N	E
BUCKWHEATS (Polygonaceae)				
□ *Polygonum amphibium* var. *emersum* [= *P. coccineum*]	water smartweed	Aug-Sep	N	E
Polygonum aviculare	prostrate knotweed or smartweed	Jun-Nov	N	E,W
Polygonum convolvulus	black bindweed	Jun-Sep	A	E
Polygonum cuspidatum	Japanese knotweed	Aug-Sep	A	W
Polygonum hydropiper	marshpepper smartweed, water-pepper	Jun-Nov	A	E,W
Polygonum hydropiperoides	swamp smartweed, water-pepper	Jun-Nov	N	E
Polygonum lapathifolium	willow-weed, nodding smartweed	Aug-Sep	N	E,W
Polygonum pensylvanicum [= *P. p.* var. *eglandulosum*]	Pennsylvania smartweed, Lake Erie pinkweed	Aug-Sep	N	E,W
Polygonum persicaria	lady's thumb	Jul-Sep	A	E,W
Polygonum punctatum	dotted or water smartweed	Aug-Sep	N	E
Polygonum sagittatum	arrow-leaf tearthumb, arrow-vine	Sep	N	E,W
Polygonum scandens	climbing false-buckwheat	Aug-Nov	N	W

BUCKWHEATS (cont'd)	**Common Name**	**Phenology**	**Origin**	**Loc**
Polygonum virginianum [= *Tovara virginiana*]	Virginia knotweed, jumpseed	Aug	N	E,W
Rumex acetosella	garden sorrel, sheep sorrel	Jun-Oct A	E,W	
Rumex crispus	curly or sour dock	Jun-Sep	A	E,W
Rumex orbiculatus	great water dock	Sep	N	E
Rumex verticillatus	swamp dock	Jun-Sep	N	E
GARCINIAS (Clusiaceae)				
Hypericum ascyron [= *H. pyramidatum*]	great St. John's-wort	Jun-Aug	N	W
Hypericum majus	large Canadian St. John's-wort	Jul-Sep	N(P)	E
Hypericum perforatum	common St. John's-wort	Jun-Sep	A	E,W
Hypericum punctatum	dotted or spotted St. John's-wort	Aug	N	E,W
LINDENS (Tiliaceae)				
Tilia americana	American basswood	Jul	N	E,W
MALLOWS (Malvaceae)				
Abutilon theophrasti	velvet-leaf	Jul-Oct	A	E,W
Hibiscus moscheutos [= *H. palustris*]	swamp rosemallow	Aug-Sep	N	E
Hibiscus trionum	flower-of-the-hour	Jul-Sep	A	E,W
Malva moschata	musk mallow	Jun-Sep	A	W
Malva neglecta	common mallow	Apr-Oct	A	W
Malva sylvestris	high mallow	Jun-Aug	A	W
SUNDEWS (Droseraceae)				
Drosera rotundifolia	round-leaf sundew	Jun-Aug	N(P)	W
ROCKROSES (Cistaceae)				
Helianthemum bicknellii [= *H. majus* misapplied]	plains frostweed	Jun-Jul	N(T)	E,W
Lechea minor	pinweed	Jul-Nov	N(T)	W
VIOLETS (Violaceae)				
Viola blanda	sweet white violet	Apr-May	N	W
Viola canadensis	Canada violet	Apr-Jun	N	E
Viola conspersa	American dog violet	May-Jul	N	E
Viola cucullata	marsh blue violet	May	N	E,W
Viola odorata	white violet	Apr-May	A	W
Viola palmata [= *V. triloba*]	three-lobed violet	Apr-May	N	W
Viola pubescens	downy or common yellow violet	May	N	E,W
Viola rostrata	long-spur violet	Apr-Jun	N	W
Viola sagittata	arrow-leaf violet	Apr-Jun	N	W
Viola sororia	woolly blue violet, freckled violet	Apr-Jun	N	E,W
Viola striata	striped cream violet, pale violet	May	N	E,W
GOURDS (Cucurbitaceae)				
Echinocystis lobata	wild mock-cucumber	Jul-Sep	N	E,W
WILLOWS (Salicaceae)				
Populus deltoides	eastern cotton-wood	Apr-May	N	E,W
Populus grandidentata	big-tooth aspen	Apr	N	E,W
Salix alba	white willow	Apr-May	A	E
Salix amygdaloides	peach-leaf willow	Apr-Jun	N	E
Salix babylonica	weeping willow	Feb-May	A	E
Salix discolor	pussy willow	Feb-May	N	W
Salix eriocephala [= *S. rigida*]	Missouri River or heart-leaf willow	Mar-Apr	N	W
Salix exigua [= *S. interior*]	sandbar willow	May-Jun	N	E,W
Salix fragilis	crack willow	Apr-Jun	A	E
Salix humilis	tall prairie willow	Mar-Jun	N	W
Salix nigra	black willow	Apr-Jun	N	E,W
CAPERS (Capparaceae)				
Polanisia dodecandra	rough-seed clammy-weed	Jul-Sep	N	E

MUSTARDS (Brassicaceae)	Common Name	Phenology	Origin	Loc
Alliaria petiolata [= *A. officinalis*]	garlic mustard	Jul-Sep	A	E,W
Arabidopsis thaliana	mouse-ear cress	Mar-Jun	A	W
Arabis laevigata	smooth rock cress	Apr-Jun	N	E,W
Barbarea vulgaris	yellow rocket, common winter-cress	Jun	A	E,W
Brassica nigra	black mustard	Jun-Oct	A	W
Brassica rapa [= *B. campestris*]	field mustard	May-Oct	A	E
Cakile edentula	American or inland searocket	Jul-Sep	N(P)	E
Capsella bursa-pastoris	common shepherd's purse	Mar-Dec	A	W
Cardamine bulbosa	bulbous bitter-cress, spring cress	Apr-Jun	N	E,W
Cardamine concatenata [= *Dentaria laciniata*]	cut-leaf toothwort	Apr-May	N	E,W
Cardamine diphylla [= *Dentaria diphylla*]	two-leaf or common toothwort	Apr-May	N	W
Cardamine douglassii	purple bitter-cress	Apr-May	N	E,W
Cardamine hirsuta	hairy bitter-cress	Mar-Apr	A	W
Cardamine pensylvanica	Pennsylvania bitter-cress	Jun-Jul	N	E,W
Draba verna [= *Erophila verna*]	whitlow-grass	Apr-May	A	W
Erysimum repandum	treacle mustard	May-Jul	A	W
Hesperis matronalis	dame's rocket	May-Jun	A	E,W
Lepidium campestre	cow cress	May-Jun	N	W
Lepidium virginicum	poor-man's pepper-grass	May-Sep	N	W
Lunaria annua	moneyplant	May-Jun	C	W
Noebeckia aquatica [= *Armoracia aquatica*, *Nasturtium lacustre*]	lakecress	May-Aug	N	E,W
Rorippa nasturtium-aquaticum [= *Nasturtium officinale*]	true water-cress	Apr-Jun	A	W
Rorippa palustris	marsh yellow-cress	Jun-Oct	N	W
Rorippa palustris ssp. *hispida* [= *R. palustris* var. *hispida*]	bog yellow-cress, marsh cress	Jun-Jul	N	E
Sinapis alba [= *Brassica hirta*]	white mustard	Jun-Aug	A	E
Sinapis arvensis [= *Brassica kaber*]	charlock	May-Jul	A	E
Sisymbrium officinale	hedge mustard	May-Oct	A	W
Thlaspi arvense	field penny-cress	Apr-Jun	A	W
HEATHS (Ericaceae)				
Epigaea repens	trailing arbutus, ground laurel	Mar-May	N	W
Gaultheria procumbens	creeping wintergreen	Jul-Aug	N	W
Vaccinium macrocarpon [= *Oxycoccus macrocarpus*]	American or large cranberry	Jun-Aug	N(P)	W
Vaccinium pallidum [= *V. vacillans*]	low or hillside blueberry	Apr-Jun	N	E,W
WINTERGREENS (Pyrolaceae)				
Chimaphila umbellata	prince's pine	Jul-Aug	N(T)	W
Pyrola americana [= *P. rotundifolia*]	round-leaf wintergreen	Jun-Aug	N	W
INDIAN PIPES (Monotropaceae)				
Monotropa uniflora	Indian-pipe	Jun-Sep	N	W
PRIMROSES (Primulaceae)				
Lysimachia ciliata	fringed loosestrife	Jul-Sep	N	E,W
Lysimachia nummularia	creeping Jennie, moneywort	Jun-Aug	A	E,W
Lysimachia quadrifolia	whorled or prairie loosestrife	Jun-Jul	N	E,W
Samolus valerandi	water pimpernel	May-Sep	N	W
HYDRANGEAS (Hydrangeaceae)				
Hydrangea arborescens	wild hydrangea	Jun-Jul	N	E
Philadelphus coronarius	mock orange, syringa	Jun-Jul	A	W
GOOSEBERRIES (Grossulariaceae)				
Ribes americanum	wild or American black currant	Apr-Sep	N	W
Ribes cynosbati	bristly gooseberry, dogberry	May-Sep	N	W

GOOSEBERRIES (cont'd)	Common Name	Phenology	Origin	Loc
Ribes rubrum [= *R. sativum*]	red currant	Apr-Jun	A	E,W
Ribes uva-crispa	garden gooseberry	May-Jun	A	E
ORPINES (Crassulaceae)				
Sedum telephium	live-forever	Aug-Sep	A	E
Sedum ternatum	wild sedum	Apr-Jun	N	W
SAXIFRAGES (Saxifragaceae)				
Heuchera americana	American alum-root	Apr-Jul	N	E,W
Mitella diphylla	two-leaf bishop's-cap, mitrewort	Apr-May	N	W
Penthorum sedoides	ditch-stonecrop	Jul-Sep	N	E
ROSES (Rosaceae)				
Agrimonia gryposepala	tall hairy grooverbur, agrimony	Jul-Aug	N	E,W
Agrimonia parviflora	small-flower groovebur	Jul-Sep	N	E,W
Agrimonia pubescens	downy agrimony	Jul-Sep	N	W
Amelanchier arborea	downy service-berry	Apr	N	E,W
Amelanchier laevis	smooth service-berry, Juneberry	Apr-Jun	N	W
Aronia melanocarpa [= *Pyrus arbutifolia melanocarpa*]	black chokeberry	Apr-Nov	N	W
Crataegus crus-galli	cockspur hawthorn	May-Oct	N	W
Crataegus mollis	downy hawthorn	Sep-Oct	N	E
Crataegus punctata	dotted hawthorn	May-Oct	N	W
Crataegus spp.	hawthorns	May-Jun	A	E,W
Duchesnea indica	Indian mock-strawberry	Apr-Jun	A	W
Fragaria vesca	woodland strawberry	May-Aug	A	W
Fragaria virginiana	Virginia or wild strawberry	Apr-Jun	N	E,W
Geum canadense	white avens	Jun	N	E,W
Geum laciniatum	rough avens	Jun	N	E,W
Geum vernum	spring or vernal avens	Apr-Jun	N	W
Malus coronaria [= *Pyrus coronaria*; *M. angustifolia*]	wild crab, southern crab-apple	Mar-May	N	E,W
Malus pumila	apple	Apr-Jun	A	E
Potentilla canadensis	running five-finger, cinquefoil	Apr-Jun	N	E
Potentilla norvegica	Norwegian or rough cinquefoil	Jun-Aug	N	E,W
Potentilla recta	rough-fruited cinquefoil	Jun-Aug	A	E,W
Potentilla simplex	old-field or common cinquefoil	Apr-Jun	N	E,W
Prunus americana	American or wild plum	May-Jun	N	E,W
Prunus avium	sweet cherry	Apr-Jul	A	W
Prunus pensylvanica	pin cherry	Apr-May	N	E
Prunus serotina	black or wild cherry	May	N	E,W
Prunus virginiana	choke cherry	Aug-Oct	N	W
Rosa blanda	smooth stem rose	Jun	N(T)	E
Rosa carolina	pasture or wild rose	Jun-Jul	N	E,W
Rosa multiflora	multiflora rose	Jun-Jul	A	E,W
Rosa palustris	swamp rose	Jun-Aug	N	E,W
Rosa setigera	prairie or climbing rose	Jun-Jul	N	E,W
Rubus allegheniensis	Allegheny blackberry	May-Jul	N	W
Rubus canadensis	smooth blackberry	Jun-Jul	N	E
Rubus flagellaris	northern dewberry	May-Jun	N	E
Rubus hispidus	bristly or running swamp blackberry	Jun-Aug	N	W
Rubus occidentalis	black raspberry	May-Jun	N	E,W
Rubus odoratus	flowering raspberry	Jun-Aug	N	E
Spiraea alba	narrow-leaf meadow-sweet	Jun-Aug	N	E
CAESALPINIAS (Caesalpiniaceae)				
Cercis canadensis	eastern redbud	Mar-May	N	E,W
Gleditsia triacanthos	honey-locust	May-Jun	N	W
Gymnocladus dioicus [= *G. canadensis*]	Kentucky coffee-tree	May	N	E,W

PEAS (Fabaceae)	**Common Name**	**Phenology**	**Origin**	**Loc**
Amorpha fruticosa	false indigo-bush	May-Jun	N	E
Amphicarpaea bracteata	American hog-peanut	Aug-Sep	N	E,W
Apios americana	American potato-bean, groundnut	Jul-Aug	N	E,W
Astragalus canadensis	Canada milkvetch	Jul-Aug	N	E
Baptisia tinctoria	wild indigo	May-Sep	N	W
Coronilla varia	crown vetch	Jun-Aug	A	W
Desmodium canadense	showy tick-trefoil	Jul-Aug	N	E,W
Desmodium canescens	hoary tick-trefoil	Jul-Sep	N	E
Desmodium ciliare	little-leaf tick-trefoil	Jul-Aug	N	W
Desmodium glutinosum	cluster-leaf tick-trefoil	Jul	N	E
Desmodium laevigatum	smooth tick-trefoil	Jul-Aug	N	E
Desmodium paniculatum	panicled tick-trefoil	Jul-Aug	N	E,W
Desmodium pauciflorum	few-flowered tick-trefoil	Jul-Aug	N(P)	W
Lathyrus latifolius	everlasting pea	Jun-Sep	A	W
Lathyrus tuberosus	tuberous vetchling	Jun-Aug	A	W
Lespedeza capitata	round-head bush clover	Jul-Sep	N	E,W
Lespedeza hirta [= *L. polystachya*]	hairy bush clover	Jul-Oct	N	W
Lespedeza virginica	Virginia bush clover	Aug-Sep	N	E
Lotus corniculatus	bird's-foot trefoil	Jun-Sep	A	W
Lupinus perennis	wild or sundial lupine	Apr-Jul	N(P)	W
Medicago lupulina	black medick	May-Sep	A	E,W
Melilotus albus [= *M. alba*]	white sweetclover	Jul-Sep	A	E,W
Melilotus officinalis	yellow sweetclover	Jun-Sep	A	E,W
Robinia pseudoacacia	black locust	May-Jun	Z	E,W
Strophostyles helvula	trailing wildbean	Jun-Sep	N	E,W
Trifolium campestre [= *T. procumbens*]	pinnate or lesser hop-clover	May-Sep	A	W
Trifolium hybridum	alsike clover	May-Oct	A	W
Trifolium pratense	red clover	May-Aug	A	E,W
Trifolium repens	white clover	All summer	A	E,W
Vicia cracca	bird vetch	Jul-Aug	A	E
Vicia sp.	vetch	May-Sep		W
OLEASTERS (Elaeagnaceae)				
Elaeagnus angustifolia	Russian olive	Jun-Jul	A	E
Elaeagnus umbellata	autumn-olive	May-Jun	A	W
WATER MILFOILS (Haloragaceae)				
Myriophyllum spicatum	Eurasian water-milfoil	Jul-Sep	N	E
Proserpinaca palustris	marsh or common mermaid-weed	Jul-Aug	N	E
LOOSESTRIFES (Lythraceae)				
Decodon verticillatus	hairy swamp-loosestrife	Jul-Sep	N	E
Lythrum alatum	winged loosestrife	Jun-Sep	N	E
Lythrum salicaria	purple loosestrife	Jun-Sep	A	E
EVENING-PRIMROSE (Onagraceae)				
Circaea lutetiana [= *C. quadrisulcata*]	common enchanter's nightshade	Jun-Aug	N	E,W
Epilobium ciliatum	hairy or northern willow-herb	Jun-Aug	N	E,W
Epilobium ciliatum ssp. *glandulosum* [= *E. glandulosum*]	willow-herb	Jul-Sep	N	E
Gaura biennis	biennial butterfly-weed or gaura	Aug-Sep	N	E
Ludwigia alternifolia	bushy seedbox	Jun-Aug	N	W
Ludwigia palustris	marsh seedbox, water-purslane	Aug	N	E
Oenothera biennis	common evening-primrose	Jun-Sep	N	E,W
Oenothera perennis [= *O. pumila*]	small evening-primrose	May-Aug	N	W
DEERGRASSES (Melastomataceae)				
Rhexia virginica	Virginia meadow-beauty, deergrass	Jul-Sep	N(P)	W
DOGWOODS (Cornaceae)				
Cornus alternifolia	alternate-leaf or pagoda dogwood	May-Sep	N	W
Cornus amomum	silky or knob-styled dogwood	May-Jul	N	E,W

DOGWOODS (cont'd)	Common Name	Phenology	Origin	Loc
Cornus drummondii	rough-leaf dogwood	May-Jun	N	E,W
Cornus florida	flowering dogwood	Apr-May	N	E,W
Cornus racemosa	gray dogwood	May-Oct	N	E,W
Cornus rugosa	round-leaved dogwood	May-Oct	N(P)	W
Cornus sericea [= *C. stolonifera*]	red-osier dogwood	May-Aug	N	E,W
Nyssa sylvatica	black gum	May-Jun	N	E,W
SANDALWOODS (Santalaceae)				
Comandra umbellata	umbellate bastard-toadflax	May-Jul	N	E
STAFF-TREES (Celastraceae)				
Celastrus scandens	American bittersweet	Jun	N	E,W
Euonymus fortunei	bigleaf or Chinese wintercreeper	May	A	E,W
HOLLIES (Aquifoliaceae)				
Ilex verticillata	common winterberry	May-Jun	N	E
SPURGES (Euphorbiaceae)				
Acalypha virginica var. *rhomboidea* [= *A. rhomboidea*]	three-seed mercury	Sep	N	E,W
Chamaesyce maculata [= *Euphorbia maculata*]	spotted broomspurge	Jun-Oct	N	W
Chamaesyce nutans [= *E. nutans*]	eyebane broomspurge	Jun-Oct	N	W
Chamaesyce polygonifolia [= *Euphorbia polygonifolia*]	seaside broomspurge, seaside spurge	Jul-Oct	N(P)	E
Euphorbia corollata	flowering spurge	Jun-Sep	N	E
Euphorbia cyparissias	cypress spurge	Apr-Aug	A	W
Euphorbia dentata	toothed spurge	Jun-Sep	N	E
BUCKTHORNS (Rhamnaceae)				
Ceanothus americanus	New Jersey tea	Jun-Jul	N	E,W
Frangula alnus [= *R. frangula*]	glossy buckthorn	May-Jul	A	W
Rhamnus cathartica	European or common buckthorn	May-Jun	A	W
GRAPES (Vitaceae)				
Parthenocissus quinquefolia [= *P. inserta*]	Virginia or thicket creeper	Jun	N	E,W
Vitis aestivalis	summer grape	May-Oct	N	E,W
Vitis labrusca	northern fox grape	May-Oct	N(P)	W
Vitis riparia	riverbank grape	May-Jul	N	E,W
Vitis vulpina [= *V. cordifolia*]	frost or chicken grape	May-Oct	N	W
FLAXES (Linaceae)				
Linum virginianum	Virginia flax	Jul-Aug	N	W
MILKWORTS (Polygalaceae)				
Polygala sanguinea	red milkwort	Jun-Oct	N	W
Polygala verticillata	whorled milkwort	Jul-Oct	N	E
BLADDER-NUTS (Staphyleaceae)				
Staphylea trifolia	American bladdernut	May	N	E
HORSE-CHESTNUTS (Hippocastanaceae)				
Aesculus glabra	Ohio buckeye	Apr-May	N	E,W
MAPLES (Aceraceae)				
Acer negundo var. *negundo* [= *Negundo aceroides*]	box-elder	Apr-Oct	N	W
Acer nigrum	black maple	May-Sep	N	W
Acer palmatum	Japanese maple		A	E
Acer platanoides	Norway maple	Apr-May	A	E,W
Acer rubrum	red maple	Mar-Apr	N	E,W
Acer saccharinum	silver maple	Mar-Apr	N	E,W

MAPLES (cont'd)	Common Name	Phenology	Origin	Loc
Acer saccharum	sugar maple	Apr-Jun	N	E,W
CASHEWS (Anacardiaceae)				
Rhus glabra	smooth sumac	Jun-Jul	N	E,W
Rhus hirta [= *R. typhina*]	staghorn sumac	Jun-Aug	N	E,W
Toxicodendron radicans [= *R. radicans*]	poison ivy	May-Jun	N	E,W
QUASSIAS (Simaroubaceae)				
Ailanthus altissima [= *A. glandulosa*]	Chinese sumach	Jun-Jul	A	W
RUES (Rutaceae)				
Zanthoxylum americanum	common prickly-ash	Apr-May	N	W
WOOD SORRELS (Oxalidaceae)				
Oxalis stricta [= *O. europaea*]	common yellow wood sorrel	Aug	N	E,W
Oxalis violacea	violet wood sorrel	Apr-Jun	N	E,W
GERANIUMS (Geraniaceae)				
Erodium cicutarium	redstem-filaree, storksbill	Apr-Oct	A	W
Geranium carolinianum	Carolina crane's-bill	May-Jul	N	W
Geranium maculatum	purple crane's-bill, wild geranium	Apr-Jun	N	E,W
Geranium pusillum	small-flowered crane's-bill	Jun-Oct	A	W
MEADOW-FOAMS (Limnanthaceae)				
Floerkea proserpinacoides	false mermaid-weed	Apr-May	N	E,W
JEWELWEEDS (Balsaminaceae)				
Impatiens capensis	spotted touch-me-not, jewelweed	Jun-Sep	N	E,W
Impatiens pallida	pale touch-me-not	Jun-Sep	N	E,W
GINSENGS (Araliaceae)				
Panax quinquefolius	American ginseng	Jul-Aug	N	W
Panax trifolius	dwarf ginseng	Apr-Jun	N	W
CARROTS (Apiaceae)				
Chaerophyllum procumbens	spreading chervil	Apr-May	N	W
Cicuta maculata	spotted water-hemlock	Jun-Aug	N	E,W
Cryptotaenia canadensis	Canada honewort	Jun-Jul	N	E,W
Daucus carota	wild carrot, Queen Anne's lace	May-Oct	A	E,W
Heracleum maximum	cow-parsnip	Jun-Aug	N	W
Osmorhiza claytonii	hairy or woolly sweetcicely	May-Jun	N	E,W
Osmorhiza longistylis	smooth sweetcicely	May-Jun	N	E,W
Pastinaca sativa	wild parsnip	May-Oct	A	W
Sanicula canadensis	Canada sanicle or black snakeroot	Jun-Aug	N	E,W
Sium suave	hemlock water-parsnip	Jul-Sep	N	E
Taenidia integerrima	yellow pimpernel	Apr-Jun	N	E
Thaspium trifoliatum	smooth meadow-parsnip	May-Jun	N	E
Zizia aurea	golden alexanders	Apr-Jun	N	W
GENTIANS (Gentianaceae)				
Bartonia virginica	yellow screwstem	Jul-Sep	N	W
Frasera caroliniensis [= *Swertia c.*]	American columbo	May-Jun	N	E,W
Gentiana andrewsii	fringe-top bottle or closed gentian	Sep	N	E
Gentianella tenella [= *Bartonia tenella*]	gentian	Aug-Sep	N	W
Gentianopsis crinita = *Gentiana crinita*]	fringed gentian	Sep-Nov	N(P)	W
Sabatia angularis	square-stem rose-gentian	Jul-Sep	N	E,W
DOGBANES (Apocynaceae)				
Apocynum cannabinum	Indian hemp	Jun-Sep	N	E,W
Apocynum sibiricum	clasping-leaf dogbane	Jun-Sep	N(E)	E
Vinca minor	periwinkle	Mar-Jun	A	W

MILKWEEDS (Asclepiadaceae)	Common Name	Phenology	Origin	Loc
Asclepias incarnata	swamp milkweed	Jun-Aug	N	E,W
Asclepias sullivantii	smooth milkweed	Jun-Jul	N	E
Asclepias syriaca	common milkweed	Jun-Aug	N	E,W
Asclepias tuberosa	butterfly-weed	Jun-Sep	N	E,W
NIGHTSHADES (Solanaceae)				
Datura stramonium	jimsonweed	Jun-Aug	Z	E,W
Physalis heterophylla	clammy ground-cherry	Jul-Sep	N	W
Physalis sp.	ground-cherry	Jun-Oct		W
Solanum carolinense	horse-nettle	May-Oct	Z	W
Solanum dulcamara	climbing or bittersweet nightshade	Jun-Sep	A	E,W
Solanum ptychanthum [=*S. nigrum* misapplied]	black or common nightshade	May-Sep	N	E,W
MORNING-GLORIES (Convolvulaceae)				
Calystegia sepium [= *Convolvulus sepium*]	hedge bindweed	May-Sep	N	E,W
Convolvulus arvensis	field bindweed	May-Sep	A	E,W
Ipomoea pandurata	wild sweet-potato vine	Jun-Sep	N	W
Ipomoea purpurea	common morning-glory	Jul-Oct	A	W
DODDERS (Cuscutaceae)				
Cuscuta gronovii	common dodder	Jul-Oct	N	E,W
Cuscuta polygonorum	smartweed dodder	Jul-Sep	N	E
PHLOXES (Polemoniaceae)				
Phlox divaricata	woodland or blue phlox	Apr-Jun	N	E,W
Phlox subulata	ground phlox, moss-pink	Apr-May	N	W
WATERLEAFS (Hydrophyllaceae)				
Hydrophyllum virginianum	Virginia waterleaf	May-Jun	N	E,W
BORAGES (Boraginaceae)				
Buglossoides arvensis [= *Lithospermum arvense*]	corn gromwell	Apr-Jun	A	W
Cynoglossum officinale	hound’s-tongue	May-Jul	A	W
Hackelia virginiana	Virginia stickseed	Jun-Sep	N	W
Mertensia virginica	Virginia bluebells or cowslip	Apr-May	N	W
Symphytum officinale	common comfrey	Jun-Aug	A	E
VERVAINS (Verbenaceae)				
Phryma leptostachya	lopseed	Jun-Aug	N	E,W
Verbena hastata	blue vervain	Jul-Sep	N	E,W
Verbena urticifolia	white vervain	Jun-Oct	N	E,W
Verbena x *illicita*	hybrid vervain	Jul-Aug	N	E
MINTS (Lamiaceae)				
Agastache nepetoides	yellow giant-hyssop	Jul-Sep	N	W
Agastache scrophulariifolia [= *Lophanthus scrophulariifolius*]	purple giant-hyssop	Jul-Sep	N	W
Collinsonia canadensis	Canada horse-balm	Jul-Sep	N	E
Glechoma hederacea	ground ivy	Apr-Jul	A	W
Lamium amplexicaule	henbit, dead nettle	Mar0Nov	A	W
Lamium purpureum	purple or red dead nettle	Apr-Oct	A	E,W
Leonurus cardiaca	motherwort, lion’s tail	Jun-Aug	A	W
Lycopus americanus	American bugleweed	Jun-Sep	N	E,W
Lycopus europaeus	European bugleweed	Jun-Sep	A	E
Lycopus rubellus	taper-leaf bugleweed	Jul-Oct	N	W
Lycopus uniflorus	northern bugleweed, water horehound	Jun-Sep	N	E
Lycopus virginicus	Virginia bugleweed	Jun-Sep	N	E,W
Lycopus x *sherardii*	hydrid water horehound	Jun-Sep	N	E

MINTS (cont'd)	Common Name	Phenology	Origin	Loc
Mentha arvensis [= *M. gentilis*]	field mint	Jul-Aug	N	E,W
Mentha spicata	spearmint	Jun-Oct	A	W
Mentha x *gracilis* [= *M.* x *cardiaca*]	small-leaf mint	Jul-Aug	A	E
Monarda fistulosa	wild bergamot	Jun-Sep	N	E,W
Nepeta cataria	catnip	Jun-Oct	A	E,W
Prunella vulgaris	heal-all, self-heal	Jun-Oct	A	E,W
Pycnanthemum virginianum	Virginia mountain-mint	Jul-Sep	N	E
Scutellaria galericulata [= *S. epilobiifolia*]	hooded or marsh skullcap	Jun-Aug	N	E
Scutellaria lateriflora	blue or mad-dog skullcap	Jul-Sep	N	E,W
Stachys tenuifolia [= *S. t.* var. *hispida*; *S. hispida*]	smooth or common hedgenettle	Jun-Aug	N	E,W
Teucrium canadense	American germander	Jun-Aug	N	E
Teucrium canadense var. *virginicum*	germander	Jul-Sep	N	W
WATER-STARWORTS (Callitrichaceae)				
Callitriche heterophylla	larger water-starwort	Apr-Dec	A	W
PLANTAINS (Plantaginaceae)				
Plantago lanceolata	English plantain	May-Oct	A	W
Plantago major	common plantain	Jul-Sep	A	E,W
Plantago rugelii	black-seed or Rugel's plantain	Jul-Oct	N	W
OLIVES (Oleaceae)				
Fraxinus americana	white ash	Apr-Jun	N	E,W
Fraxinus pennsylvanica [= *F. p.* var. *subintegerrima*]	green ash	May	N	E
Ligustrum vulgare	common or European privet	Jun	A	E,W
FIGWORTS (Scrophulariaceae)				
Agalinis tenuifolia	slender false-foxglove or gerardia	Jul-Sep	N	W
Antirrhinum majus	common snapdragon	Jun-Sep	A	E
Aureolaria flava	smooth false-foxglove	Jul-Sep	N	W
Chaenorrhinum minus	lesser toadflax	Jun-Sep	A	E
Chelone glabra	white turtlehead	Jul-Sep	N	E,W
Gratiola neglecta	clammy hedgehyssop	May-Oct	N	W
Linaria vulgaris	butter-and-eggs	Jul-Aug	A	E
Lindernia dubia	yellow-seed false-pimpernel	Jul-Sep	N	E
Mimulus alatus	sharp-wing monkey-flower	Jun-Aug	N	E,W
Mimulus ringens	Allegheny or common monkey-flower	Jun-Sep	N	E,W
Pedicularis lanceolata	swamp lousewort	Aug-Sep	N	E,W
Penstemon hirsutus	hairy beardtongue	May-Jul	N	E
Scrophularia lanceolata	lance-leaf or American figwort	May-Jul	N	E
Scrophularia marilandica	carpenter's square	Jun-Oct	N	W
Verbascum blattaria	moth mullein	Jun-Sep	A	W
Verbascum thapsus	common or woolly mullein	Jun-Sep	A	E,W
Veronica anagallis-aquatica [=*V. anagallis*]	water speedwell	May-Oct	N	W
Veronica arvensis	corn speedwell	Apr-Sep	A	E,W
Veronica officinalis	common speedwell	May-Jul	A	W
Veronica peregrina	purslane speedwell	Mar-Aug	N	W
Veronica polita	slender speedwell	Mar-May	A	W
Veronica serpyllifolia	thyme-leaf speedwell	May-Aug	A	E,W
Veronicastrum virginicum	Culver's-root	Jun-Aug	N	E
BROOM-RAPES (Orobanchaceae)				
Epifagus virginiana	beech-drops	Aug-Oct	N	W

BIGNONIAS (Bignoniaceae)	Common Name	Phenology	Origin	Loc
Campsis radicans	trumpet creeper	Jul-Aug	Z	E,W
Catalpa bignonioides	southern catalpa	Jun-Jul	C	E
Catalpa speciosa	northern catalpa	May-Jun	Z	W
BLUEBELLS (Campanulaceae)				
Lobelia cardinalis	cardinal flower	Jul-Sep	N	E
Lobelia inflata	Indian-tobacco	Jul-Oct	N	E,W
Lobelia siphilitica	great blue lobelia	Aug-Sep	N	E,W
Triodanis perfoliata [= *Specularia p.*]	clasping-leaf Venus'-looking-glass	May-Jun	N	E,W
MADDERS (Rubiaceae)				
Cephalanthus occidentalis	common buttonbush	Jun-Aug	N	E,W
Galium aparine	catchweed bedstraw, cleavers	May-Jul	N	E,W
Galium asprellum	rough bedstraw	May-Aug	N	E
Galium circaezans	forest bedstraw	Jun-Jul	N	E,W
Galium lanceolatum	wild licorice	Jun-Jul	N	W
Galium mollugo	wild madder	Jun-Aug	A	W
Galium obtusum	blunt-leaf bedstraw	May-Jul	N	W
Galium tinctorium	stiff marsh bedstraw	Jun-Aug	N	E
Galium trifidum	small bedstraw	Jul-Sep	N	W
Galium triflorum	sweet-scent bedstraw	Jun-Aug	N	E,W
Houstonia caerulea [= *Hedyotis caerulea*]	innocence, bluets	Apr-Jun	N	E,W
Mitchella repens	partridge-berry	Jun-Jul	N	W
HONEYSUCKLES (Caprifoliaceae)				
Lonicera dioica var. *dioica*	mountain honeysuckle	May-Jun	N	E
Lonicera dioica var. *glaucescens*	wild honeysuckle	May-Jun	N	E
Lonicera japonica	Japanese honeysuckle	May-Sep	N	E,W
Lonicera maackii	amur honeysuckle		A	W
Lonicera tatarica	tartarian or bush honeysuckle	May-Jun	A	W
Sambucus nigra ssp. *canadensis* [= *S. canadensis*]	American elder, common elderberry	Jun-Jul	N	E,W
Sambucus racemosa	European red elder	May-Jun	N	W
Triosteum perfoliatum	tinker's weed, perfoliate horse-gentian	May-Jul	N	E,W
Viburnum acerifolium	maple-leaf viburnum, dockmackie	May-Jun	N	E,W
Viburnum dentatum	arrow-wood	May-Jul	N	W
Viburnum dentatum var. *lucidum* [= *V. recognitum*]	southern arrow-wood	May-Jul	N	E,W
Viburnum lentago	nannyberry	May-Jun	N	E,W
Viburnum opulus	guelder rose, Euro cranberry	Jun-Jul	A	E,W
Viburnum prunifolium	black-haw	Apr-May	N	E
VALERIANS (Valerianaceae)				
Valerianella radiata	beaked cornsalad	Apr-May	N	E,W
Valerianella locusta [= *V. olitoria*]	European cornsalad	Apr-Jun	A	W
Valerianella umbilicata	navel-shape cornsalad	May-Jun	N	E
Valerianella woodsiana	Woods' cornsalad	May-Jun	N	W
TEASELS (Dipsacaceae)				
Dipsacus fullonum ssp. *sylvestris* [= *D. sylvestris*]	teasel	Jul-Sep	A	E,W
COMPOSITES (Asteraceae)				
Achillea millefolium	common yarrow	Jun-Oct	N	E,W
Ageratina altissima [= *Eupatorium rugosum*; *E. ageratoicles*]	white snakeroot	Jul-Oct	N	E,W
Ambrosia artemisiifolia	annual or common ragweed	Aug-Sep	N	E,W
Ambrosia trifida	great or giant ragweed	Jul-Oct	N	E,W
Antennaria neglecta	field pussytoes	Apr-Jul	N	W
Antennaria parlinii	Parlin's everlasting pusseytoes	Apr-Jun	N	W
Antennaria plantaginifolia	plantain pussytoes	Apr-Aug	N	E

COMPOSITES (cont'd)	Common Name	Phenology	Origin	Loc
Arctium minus	common burdock	Jul-Oct	A	E,W
Arnoglossum atriplicifolium [= *Cacalia atriplicifolia*]	pale Indian-plantain	Jul-Sep	N	E
Artemisia campestris	beach wormwood	Jul-Sep	N(T)	E
Artemisia campestris ssp. *caudata*	wormwood [= *A. caudata*]	Jul-Sep	N	E
Artemisia vulgaris	mugwort	Jul-Aug	A	W
Aster boreaus [= *A. junciformis*]	rush aster	Jun-Sep	N	W
Aster cordifolius	common blue heart-leaved aster	Aug-Oct	N	E,W
Aster cordifolius var. *sagittifolius* [= *A. sagittifolius*]	arrow-leaved aster	Aug-Oct	N	E,W
Aster dumosus	bush aster	Aug-Oct	N(T)	E
Aster ericoides	white heath aster	Jul-Oct	N	E
Aster laevis	smooth aster	Aug-Oct	N	E
Aster lanceolatus [= *A. paniculatus*; *A. simplex*]	panicled aster	Aug-Oct	N	E,W
Aster lateriflorus [= *A. vimineus*]	calico aster	Aug-Oct	N	E,W
Aster longifolius [= *A. junceus*]	New York aster	Jul-Oct	N	W
Aster macrophyllus	big-leaf aster	Aug-Sep	N	W
Aster novae-angliae	New England aster	Aug-Oct	N	E,W
Aster oolentangiensis [= *A. azureus*]	prairie heart-leaved aster	Aug-Oct	N	E
Aster pilosus	awl aster	Aug-Oct	N	W
Aster pilosus var. *demotus* [= *A. racemosus*]	coastal-plain aster	Oct	N	E,W
Aster praealtus	willow-leaf aster	Sep-Oct	N	E
Aster prenanthoides	crooked-stem aster	Aug-Oct	N	W
Aster shortii	midwestern blue heart-leaved aster	Aug-Oct	N	E
Aster undulatus	clasping heart-leaved aster	Aug-Oct	N	E
Bidens cernua	nodding beggar-ticks	Sep-Oct	N	E,W
Bidens connata	purple-stem beggar-ticks	Sep-Oct	N	E
Bidens frondosa	devil's beggar-ticks	Sep-Oct	N	E,W
Bidens laevis	smooth beggar-ticks, tickseed	Aug-Nov	N	E
Bidens vulgata	tall beggar-ticks	Aug-Oct	N	W
Cichorium intybus	chicory	Jun-Oct	A	E,W
Cirsium arvense	creeping thistle	Jul-Oct	A	E,W
Cirsium muticum	swamp thistle	Jul-Sep	N	W
Cirsium vulgare	bull thistle	Jul-Sep	A	E,W
Conyza canadensis [= *Erigeron canadensis*]	horseweed	late summer- autumn	N	E,W
Coreopsis tripteris	tall tickseed	Jul-Sep	N	E,W
Eclipta prostrata [= *E. alba*]	yerba de tajo, pie-plate-plant	Aug-Oct	N	E
Erechtites hieraciifolia	American burn, pilewort	Jul-Oct	N	W
Erigeron annuus	white-top fleabane	Jun-Oct	N	E,W
Erigeron philadelphicus	Philadelphia or daisy fleabane	Apr-May	N	E,W
Erigeron strigosus	prairie fleabane	Jun-Aug	N	E,W
Eupatorium altissimum	tall eupatorium	Jul-Sep	N	E
Eupatorium maculatum	spotted Joe-pye-weed	Jul-Sep	N	E,W
Eupatorium perfoliatum	common boneset	Jul-Oct	N	E,W
Eupatorium pilosum	hairy thoroughwort	Aug-Sep	N	E
Eupatorium purpureum	sweet Joe-pye-weed	Jul-Sep	N	W
Euthamia graminifolia	flat-top fragrant-golden-rod	Jul-Oct	N	E,W
Euthamia tenuifolia	narrow-leaf fragrant-golden-rod	Aug-Oct	N	E
Galinsoga parviflora	lesser quickweed or galinsoga	Jun-Oct	A	E,W
Galinsoga quadriradiata	common quickweed or galinsoga	Jun-Nov	A	W
Helenium autumnale	common sneezeweed	Aug-Oct	N	E
Helianthus annuus	common or garden sunflower	Jul-Oct	C	W
Helianthus divaricatus	divaricate sunflower	Jul-Oct	N	E
Helianthus hirsutus	hairy sunflower	Jul-Oct	N	E
Helianthus strumosus	rough-leaved sunflower	Jul-Sep	N	E
Helianthus tuberosus	Jerusalem artichoke	Aug-Oct	N	E,W

COMPOSITES (cont'd)	Common Name	Phenology	Origin	Loc
Heliopsis helianthoides	ox-eye, sunflower-everlasting	Jul-Oct	N	E
Hieracium aurantiacum	orange-red king-devil or hawkweed	Jun-Sep	A	E,W
Hieracium caespitosum [= *H. pratense*]	yellow king-devil, field hawkweed	May-Sep	A	E,W
Hieracium paniculatum	panicled hawkweed	Jul-Sep	N	W
Hieracium pilosella	mouse-ear hawkweed	Jun-Sep	A	W
Hieracium venosum	veiny hawkweed	May-Jul	N	E
Hieracium x floribundum	smoothish hawkweed	Jun-Aug	A	W
Krigia biflora	two-flower dwarf-dandelion, Cynthia	May-Oct	N	E
Lactuca biennis	biennial or tall blue lettuce	Jul-Oct	N	W
Lactuca canadensis	tall yellow or wild lettuce	Jul-Sep	N	E,W
Lactuca floridana	woodland lettuce	Jun-Sep	N	E
Lactuca serriola	prickly lettuce	Jul-Sep	A	W
Leucanthemum vulgare [= *Chrysanthemum leucanthemum*]	oxeye daisy	Jun-Aug	A	W
Liatris spicata	spiked gayfeather, blazing star	Jul-Sep	N	E,W
Matricaria discoidea	pineapple-weed	May-Sep	Z	W
Oligoneuron ohioense [= *Solidago ohioensis*]	Ohio golden-rod	Aug-Sep	N(P)	E
Picris hieracioides	hawkweed oxtongue, bitterweed	Jul-Sep	A	W
Prenanthes alba	white rattlesnake-root or lettuce	Aug-Sep	N	E,W
Prenanthes serpentaria	lion's foot	Aug-Oct	N	E
Rudbeckia fulgida	orange coneflower	Jul-Oct	N	E
Rudbeckia hirta	black-eyed Susan	Jun-Oct	N	E,W
Rudbeckia laciniata	cut-leaf or greenheaded coneflower	Jul-Sep	N	E,W
Senecio aureus	golden ragwort	Apr-Aug	N	E,W
Senecio glabellus	grass-leaf groundsel	May-Jul	N	E
Senecio obovatus [= *S. rotundus*]	round-leaf groundsel	Apr-Jun	N	E,W
Senecio vulgaris	common groundsel	May-Oct	A	W
Silphium perfoliatum	cup-plant	Jul-Sep	N	W
Silphium trifoliatum	whorled rosinweed	Jul-Sep	N	E,W
Solidago caesia	wreath golden-rod	Aug-Oct	N	E,W
Solidago canadensis	Canada golden-rod	Jul-Sep	N	E,W
Solidago flexicaulis [= *S. latifolia*]	zigzag golden-rod	Jul-Oct	N	W
Solidago gigantea	giant golden-rod	Aug-Oct	N	E
Solidago juncea	early golden-rod	Jul-Sep	N	E
Solidago nemoralis	gray golden-rod	Jul-Nov	N	W
Solidago patula	rough-leaf golden-rod	Aug-Oct	N	W
Solidago rugosa	wrinkled golden-rod	Aug-Oct	N	E,W
Solidago speciosa	showy golden-rod	Aug-Oct	N	E
Solidago ulmifolia	elm-leaved golden-rod	Aug-Oct	N	E
Sonchus arvensis	field sowthistle	Jul-Oct	A	W
Sonchus asper	prickly sowthistle	Jun-Oct	A	E,W
Sonchus oleraceus	common sowthistle	Jun-Oct	A	W
Taraxacum officinale	common dandelion	Mar-Dec	A	E,W
Tragopogon porrifolius	salsify	May-Jul	A	W
Tragopogon pratensis	goats-beard	Jun-Oct	A	W
Tussilago farfara	colts-foot	Mar-May	A	W
Verbesina alternifolia [= *Actinomeris alternifolia*]	wingstem	Aug-Oct	N	E,W
Verbesina occidentalis [= *Actinomeris occidentalis*]	southern flatseed-sunflower, yellow crownbeard	Jun-Oct	N(E)	E
Vernonia gigantea [= *V. altissima*]	tall ironweed	Aug-Oct	N	E,W
Xanthium strumarium [= *Solidago tenuifolia*]	rough cockle-bur	Aug-Sep	N	E,W
FLOWERING RUSHES (Butomaceae)				
Butomus umbellatus	flowering-rush	Jun-Sep	A	E

WATER-PLANTAINS (Alismataceae)	Common Name	Phenology	Origin	Loc
Alisma subcordatum	subcordate water-plantain	Jun-Sep	N	E
Alisma triviale [= *A. plantago-aquatica* var. *americanum*]	broad-leaf water-plantain	Jun-Sep	N(T)	E
Sagittaria latifolia	broad-leaf arrow-head	Jul-Sep	N	E,W
FROG'S-BITES (Hydrocharitaceae)				
Elodea canadensis	broad water-weed	Jul-Sep	N	E,W
PONDWEEDS (Potamogetonaceae)				
Potamogeton crispus	curly pondweed	May-Sep	A	E
Potamogeton foliosus	leafy pondweed	Jul-Oct	N	E
Potamogeton nodosus	long-leaf pondweed	Aug-Sep	N	E
Potamogeton pectinatus	sago pondweed	Jul-Aug	N	E
SWEETFLAGS (Acoraceae)				
Acorus americanus	sweetflag	May-Jun	N	E,W
Acorus calamus	sweetflag	May-Jun	N	E
ARUMS (Araceae)				
Arisaema dracontium	green dragon	May-Jun	N	W
Arisaema triphyllum [= *A. atrorubens*]	swamp Jack-in-the-pulpit	Apr-Jun	N	E,W
Peltandra virginica	arrow arum	May-Jun	N	E
Symplocarpus foetidus	skunk-cabbage	Mar-Apr	N	E,W
DUCKWEEDS (Lemnaceae)				
Lemna minor	lesser duckweed	Jun-Aug	N	E,W
Spirodela polyrrhiza	greater duckweed	Jun-Aug	A	E
Wolffia columbiana	Columbia water-meal, wolffia		N	E,W
SPIDERWORTS (Commelinaceae)				
Commelina communis	Asiatic dayflower	Jun-Oct	A	E,W
Tradescantia virginiana	Virginia spider-wort	spring	N	E
RUSHES (Juncaceae)				
Juncus acuminatus	taper-tip rush	May-Aug	N	E
Juncus biflorus	turnflower rush	May-Sep	N	W
Juncus canadensis	Canada rush	Jul-Oct	N	W
Juncus effusus	soft rush	Aug	N	E,W
Juncus marginatus	grass-leaf rush	Jun-Sep	N	W
Juncus nodosus	knotted rush	Jul-Aug	N	W
Juncus tenuis	slender or path rush	May-Jul	N	E,W
Juncus torreyi	Torrey's rush	Jul-Oct	N	W
Luzula multiflora	common woodrush	Apr-Jul	N	E
SEDGES (Cyperaceae)				
Bolboschoenus fluviatilis [= *Scirpus fluviatilis*]	river bulrush	Jun-Aug	N	E
Bulbostylis capillaris [= *Fimbristylis capillaris*]	dense-tuft hairsedge	Aug-Oct	N	W
Carex albicans [= *C. artitecta*]	closely-covered sedge	May-Aug	N	E
Carex albursina [= *C. laxiflora* var. *latifolia*]	loose-flowered sedge	Apr-Jun	N	W
Carex amphibola var. *turgida* [= *C. grisea*]	narrow-leaf sedge	May-Jul	N	E,W
Carex annectens	yellow-fruit sedge	May-Jul	N	E
Carex aquatilis	water or leafy tussock sedge	Jul-Aug	N(T)	E
Carex arctata	northern clustered sedge	Jun-Aug	N(E)	W
Carex atherodes	slough sedge	Jun-Aug	N(P)	E
Carex bebbii	Bebb's sedge	Jun-Aug	N(P)	E
Carex bicknellii	Bicknell's sedge	May-Jul	N(T)	E,W
Carex blanda	woodland sedge	Apr-Jun	N	E,W
Carex brevior	shorter sedge	May-Jul	N	E
Carex bromoides	brome-like sedge	May-Jul	N	W

SEDGES (cont'd)	Common Name	Phenology	Origin	Loc
Carex cephalophora	oval-leaf sedge	May-Jul	N	E
Carex comosa	bearded or longhair sedge	Jun-Aug	N	E
Carex complanata	hirsute sedge	May-Jul	N	E
Carex conjuncta	soft fox sedge	Jun	N	W
Carex crinita	fringed sedge	May-Aug	N	E,W
Carex crus-corvi	raven-foot sedge	Jun-Jul	N(E)	E
Carex davisii	Davis' sedge	May-Jun	N	W
Carex digitalis	finger sedge	May-Jul	N	E,W
Carex echinata [= *C. cephalantha*]	little prickly sedge	Jul-Sep	N(E)	E
Carex frankii	Frank's sedge	Jun-Jul	N	E,W
Carex glaucodea [= *C. flaccosperma* var. *glaucodea*]	thin-fruit sedge	May-Jul	N	W
Carex granularis	meadow sedge	May-Jul	N	W
Carex grayi	Asa Gray's sedge	Jun-Oct	N	E,W
Carex hirsutella	slightly hirsute sedge	May-Jul	N	E
Carex hirtifolia	hairy-leaved sedge	May-Jun	N	W
Carex intumescens	bladder sedge	May-Sep	N	E,W
Carex jamesii	James' sedge	May-Jun	N	W
Carex lacustris	lakebank sedge	May-Aug	N	E
Carex lasiocarpa	woolly-fruit sedge	May-Aug	N(P)	E,W
Carex laxiculmis [= *C. digitalis copulata*]	loose-culmed sedge	May-Jul	N	W
Carex laxiflora [= *C. laxiflora patulifolia*]	loosely-flowered sedge	Apr-Jun	N	W
Carex lupulina	hop sedge	Jun-Oct	N	E,W
Carex lurida	shallow sedge	Jun-Oct	N	W
Carex normalis	larger straw sedge	May-Aug	N	W
Carex oligocarpa	few-fruited sedge	May-Jul	N	W
Carex pallescens	rather pale sedge	May-Aug	N(T)	W
Carex pedunculata	peduncled sedge	Apr-May	N	W
Carex pensylvanica	Pennsylvania sedge	Apr-Jun	N	E,W
Carex projecta	necklace sedge	Jun-Aug	N(T)	W
Carex radiata	radiate sedge	May-Aug	N(P)	E
Carex retroflexa	reflexed sedge	May-Jun	N(P)	E
Carex rosea [= *C. convuluta*]	rose-like sedge	May-Jul	N	E,W
Carex scoparia	pointed broom sedge	May-Aug	N	W
Carex shortiana	Short's sedge	May-Jun	N	W
Carex squarrosa	squarrose sedge	Jun-Sep	N	E,W
Carex stipata	awl-fruited sedge	May-Aug	N	E,W
Carex straminea [= *C. straminea mirabilis*]	straw sedge	May-Jul	N(P)	W
Carex striatula [= *C. laxiflora* var. *angustifolia*]	lined sedge	May-Jun	N(E)	W
Carex tribuloides	blunt broom sedge	Jun-Sep	N	E
Carex typhina [= *C. typhinoides*]	cat-tail sedge	Jun-Sep	N	W
Carex vesicaria var. *monile* [= *C. monile*]	inflated sedge	Jun-Aug	N	W
Carex virescens [= *C. virescens* var. *costata*]	greenish sedge	May-Jul	N	W
Carex vulpinoidea	fox sedge	Jun-Jul	N	E,W
Cyperus bipartitus [= *C. rivularis*]	shining flatsedge	Sep	N	E
Cyperus erythrorhizos	red-root flatsedge, umbrella-sedge	Aug-Oct	N	E
Cyperus esculentus	chufa	Sep	N	E,W
Cyperus filiculmis	slender flatsedge, nutsedge	Aug-Oct	N	W
Cyperus odoratus [= *C. ferruginescens*; *C. engelmannii*]	rusty or Englemann flatsedge	Aug-Sep	N	E
Cyperus schweinitzii	Schweinitz's flatsedge	Jul-Sep	N(P)	W
Cyperus strigosus	straw-color flatsedge, galingale	Sep	N	E
Eleocharis obtusa	blunt spikerush	May-Oct	N	W
Eleocharis ovata	ovate spikerush	Aug-Oct	N(E)	E
Rhynchospora glomerata [= *R. cymosa*]	clustered beakrush	Jul-Oct	N	W
Schoenoplectus pungens [= *Scirpus americanus*; *S. pungens*]	three-square bulrush	Jul-Aug	N	E

SEDGES (cont'd)	Common Name	Phenology	Origin	Loc
Schoenoplectus tabernaemontani [= *Scirpus validus*; *S. v.* var. *creber*]	soft-stem or great bulrush	Jul-Aug	N	E,W
Scirpus atrovirens	green bulrush	Jun-Aug	N	E,W
Scirpus cyperinus	wool-grass	Jun-Sep	N	E,W
Scirpus pedicellatus	stalked bulrush	Jul-Aug	N	E
Scirpus polyphyllus	leafy bulrush	Jul-Sep	N	W
Scleria pauciflora	few-flower nutrush	Jun-Sep	N(T)	W
Scleria triglomerata	whip nutrush	Jun-Sep	N(P)	W
GRASSES (Poaceae)				
Aegilops cylindrica	jointed goat-grass	Jul-Sep	A	E
Agrostis stolonifera	spreading bentgrass	Jun-Sep	N	E
Ammophila breviligulata	American beachgrass	Jul-Sep	N(T)	W
Andropogon gerardii	big bluestem	Aug-Sep	N	E
Andropogon virginicus	broom-sedge		N	W
Brachyelytrum erectum	erect grass	Jun-Aug	N	W
Bromus arvensis	field chess	Jun-Jul	A	W
Bromus hordeaceus [= *B. mollis*]	soft chess	May-Jul	A	W
Bromus japonicus	Japanese brome	Jul-Aug	A	E
Bromus kalmii	Kalm's brome	Jun-Aug	N	E
Calamagrostis canadensis	blue-joint reedgrass	Jun-Sep	N	E
Cenchrus incertus [= *C. pauciflorus*]	few-flower sandbur	Jul-Oct	A	E
Cinna arundinacea	stout wood-reed grass	Aug	N	E
Dactylis glomerata	orchard grass	May-Sep	A	W
Danthonia compressa	flattened oatgrass	Jun-Aug	N(P)	W
Danthonia spicata	poverty oatgrass	May-Jul	N	W
Dichanthelium acuminatum var. *fasciculatum* [= *Panicum lanuginosum*; *P. l.* var. *implicatum*]	panic grass	Jun-Sep; Jul-Nov	N	E,W
Dichanthelium depauperatum [= *Panicum depauperatum*]	impoverished panic grass	May-Aug; Jul-Oct	N(E)	W
Dichanthelium dichotomum [= *Panicum dichotomum*; *P. barbulatum*]	cypress witchgrass	May-Jul; Jun-Nov	N	W
Digitaria ischaemum	small crabgrass	Jul-Oct	A	W
Digitaria sanguinalis	hairy crabgrass	Sep-Oct	A	E,W
Echinochloa crus-galli	barnyard grass	Sep	A	E,W
Echinochloa muricata [= *E. pungens*]	rough barnyard grass	Jul-Sep	N	E
Echinochloa walteri	coast cockspur, Walter's millet	Sep	N	E
Eleusine indica	India goosegrass	Jul-Oct	A	W
Elymus canadensis	nodding wild-rye	Jul-Oct	N	E
Elymus caninus [= *Agropyron caninum*]	cutting wheatgrass	Jun-Aug	A	W
Elymus hystrix [= *Hystrix patula*]	bottlebrush grass	Jun-Aug	N	E,W
Elymus trachycaulus ssp. *subsecundus* [= *Agropyron trachycaulum* var. *glaucum*]	slender wheatgrass	Jun-Aug	N	W
Elymus villosus	hairy wild-rye	Jun-Aug	N	E
Elymus virginicus	Virginia wild-rye	Jul-Sep	N	E,W
Elytrigia repens [= *Agropyron repens*]	quackgrass	Jun-Aug	A	W
Eragrostis pectinacea	purple lovegrass	Aug-Sep	N	E,W
Glyceria striata	fowl manna grass	May-Sep	N	E,W
Leersia oryzoides	rice cutgrass	Aug	N	E,W
Leersia virginica	whitegrass	Jul-Oct	N	E,W
Lolium pratense [= *Festuca elatior*]	tall fescue	Jun-Aug	A	W
Muhlenbergia schreberi	nimble will	Jul-Nov	N	W
Nardus stricta	mat grass	Jun-Sep	A	E
Panicum capillare	witchgrass	Sep	N	E,W
Panicum virgatum	switchgrass	Jul-Sep	N	E
Phalaris arundinacea	reed canary grass	Jun-Sep	Z	E,W
Phleum pratense	timothy	Jul-Aug	A	E,W

GRASSES (cont'd)	Common Name	Phenology	Origin	Loc
Phragmites australis	common reed	Jul-Sep	Z	E,W
Poa compressa	Canada bluegrass	May-Sep	A	E,W
Poa pratensis	Kentucky bluegrass	May-Aug	Z	E,W
Poa sylvestris	woodland bluegrass	Apr-Jun	N	E
Poa trivialis	rough bluegrass	Jun-Aug	A	W
Schizachyrium scoparium [= *Andropogon scoparius*]	little bluestem	Sep-Oct	N	E
Setaria faberi	Faber's fox-tail grass	Aug-Sep	A	E,W
Setaria glauca	yellow bristle grass	Sep	A	E,W
Sorghastrum nutans	Indian grass	Sep	N	E
Sorghum halepense	Johnson grass	Jul-Sep	A	E
Tridens flavus [= *Triodia flava*]	purple-top tridens	Aug-Oct	N	W
Triplasis purpurea	purple sand-grass	Aug-Oct	N(P)	E
Vulpia octoflora var. *glauca* [= *Festuca tenella*]	six-weeks fescue	May-Jun	N	W
BUR-REEDS (Sparganiaceae)				
Sparganium americanum	American bur-reed	Jun-Sep	N	W
Sparganium eurycarpum	giant bur-reed	Jun-Sep	N	E
CATTAILS (Typhaceae)				
Typha angustifolia	narrow-leaf cattail	May-Jul	Z	E,W
Typha x *glauca*	blue cattail	May-Jul	N	E
Typha latifolia	broad-leaf or common cattail	May-Jul	N	E,W
PICKERELWEEDS (Pontederiaceae)				
Pontederia cordata	pickerel weed	Jun-Oct	N	E
LILIES (Liliaceae)				
Allium canadense	meadow onion	May-Jul	N	E,W
Allium sativum	garlic	May-Jun	A	E
Allium tricoccum	small white leek	Jun-Jul	N	W
Allium vineale	field garlic	May-Jul	A	W
Asparagus officinalis	garden asparagus-fern	May-Jun	A	E,W
Camassia scilloides	Atlantic camassia, wild hyacinth	May-Jun	N	W
Chamaelirium luteum [= *C. carolinianum*]	fairy-wand, blazing-star	May-Jul	N	W
Convallaria majalis	lily-of-the-valley	Apr-Jun	C	W
Disporum lanuginosum	fairy bells, yellow mandarin	May-Jun	N	W
Erythronium albidum	white fawnlily or trout-lily	Mar-May	N	E,W
Erythronium americanum	yellow fawnlily or trout-lily	Mar-May	N	E,W
Hemerocallis fulva	common orange day-lily	Jun-Aug	C	E,W
Hypoxis hirsuta	eastern yellow stargrass	Jun-Sep	N	E
Lilium canadense	Canada lily	Jun-Aug	N	E
Lilium michiganense	Michigan lily	Jun-Jul	N	E
Lilium sp.	lily	Jun-Sep		W
Maianthemum canadense [= *M. convallaria*]	wild-lily-of-the-valley or Canada mayflower	May-Jul	N	W
Maianthemum racemosum [= *Smilacina racemosa*]	feather false-Solomon's-seal	May-Jul	N	E,W
Medeola virginiana	Indian cucumber-root	MayJun	N	W
Ornithogalum umbellatum	common star of Bethlenem	Apr-Jun	A	W
Polygonatum biflorum	small Solomon's-seal	Apr-Jun	N	E
Polygonatum pubescens	hairy Solomon's-seal	May-Jun	N	W
Trillium flexipes	white or drooping trillium	Apr-Jun	N	E,W
Trillium grandiflorum	large- or grand-flowered trillium	Apr-May	N	E,W
Uvularia grandiflora	large flowered bellwort	Apr-Jun	N	W
Uvularia sessilifolia	sessile-leaf bellwort, merry-bells	May-Jun	N	W
IRISES (Iridaceae)				
Iris pseudacorus	yellow iris	May-Jul	A	E,W
Iris versicolor	blueflag	May-Jul	N	E,W

IRISES (cont'd)	Common Name	Phenology	Origin	Loc
Sisyrinchium albidum	blue-eye-grass	May-Jun	N	E
Sisyrinchium mucronatum [= *S. montanum* misapplied]	Michaux's blue-eye-grass	May-Jun	N(E)	E
Sisyrinchium sp.	blue-eye-grass	May		W
CATBRIERS (Smilacaceae)				
Smilax ecirrata	erect carrion-flower	May	N	W
Smilax herbacea	smooth carrion-flower	May-Jun	N	W
Smilax rotundifolia	common greenbrier	Apr-Jun	N	W
Smilax tamnoides [= *S. hispida*]	bristly greenbrier	May-Jul	N	E,W
YAMS (Dioscoreaceae)				
Dioscorea quaternata	four-leaf yam	May	N	E
Dioscorea villosa	yellow or wild yam	Jun-Jul	N	E,W
ORCHIDS (Orchidaceae)				
Coeloglossum viride	long-bract-green orchid	Jun-Aug	N(E)	W
Epipactis helleborine [= *E. latifolia*]	helleborine	Jul-Sep	A	E
Galearis spectabilis [= *Orchis spectabilis*]	showy orchis	Apr-Jun	N	W
Goodyera pubescens	downy rattlesnake-plantain	Jul-Aug	N	W
Pogonia ophioglossoides [= *P. pendula*]	rose pogonia	Jun-Aug	N(T)	W
Spiranthes cernua	nodding ladies'-tresses	Aug-Sep	N	E
Spiranthes magnicamporum	great plains ladies'-tresses	Sep-Oct	N(P)	E
Spiranthes ochroleuca	ladies'-tresses	Aug-Sep	N	W
Triphora trianthophora	three-birds orchid	Jul-Sep	N(T)	W

Origin (and Status) Codes:

A – Alien species
C – Escaped from cultivation
N – Native species
Z – Native to North America, but later naturalized to Old Woman Creek watershed

(E) – Endangered (Ohio)
(P) – Potentially threatened (Ohio)
(T) – Threatened (Ohio)

Location Codes:

E - Estuary
W- Watershed

APPENDIX C. INVERTEBRATE FAUNA OF OLD WOMAN CREEK ESTUARY, WATERSHED, AND ADJACENT WATERS OF LAKE ERIE

PHYLUM SARCOMASTIGOPHORA (PROTOZOA)

Subphylum Mastigophora

CLASS DINOFLAGELLATA Order Gymnodinida	Common Name	Family	Location
Gymnodinium fungiforme	dinoflagellate	Gymnodiniidae	ES
CLASS PHYTOMASTIGOPHORA			
Order Cryptomonadida			
Chilomonas sp.	cryptomonad protozoan	Cryptomonadidae	ES
Chroomonas norstedtii	cryptomonad protozoan	Cryptomonadidae	ES
Cryptomonas compressa	cryptomonad protozoan	Cryptomonadidae	ES
Cryptomonas erosa	cryptomonad protozoan	Cryptomonadidae	ES
Cryptomonas obovata	cryptomonad protozoan	Cryptomonadidae	ES
Cryptomonas ovata	cryptomonad protozoan	Cryptomonadidae	ES
Cryptomonas reflexa	cryptomonad protozoan	Cryptomonadidae	ES
Cryptomonas tenuis	cryptomonad protozoan	Cryptomonadidae	ES
Cyathomonas truncata	cryptomonad protozoan	Cryptomonadidae	ES
Planonephros parvula [=*Sennia parvula*]	cryptomonad protozoan	Hemiselmidae	ES
Rhodomonas lacustris	cryptomonad protozoan	Cryptomonadidae	ES
Rhodomonas lens	cryptomonad protozoan	Cryptomonadidae	ES
Rhodomonas minuta	cryptomonad protozoan	Cryptomonadidae	ES
Order Chrysomonadida			
Anthophysa steinii	chrysomonad protozoan	Anthophysidae	ES
Anthophysa vegetans	chrysomonad protozoan	Anthophysidae	ES
Chromulina nana	chrysomonad protozoan	Chromulinidae	ES
Dinobryon bavaricum	chrysomonad protozoan	Dinobryonidae	ES
Dinobryon sertularia	chrysomonad protozoan	Dinobryonidae	ES
Mallomonas elegans	chrysomonad protozoan	Mallomonadidae	ES
Mallomonas intermedia	chrysomonad protozoan	Mallomonadidae	ES
Microglena sp.	chrysomonad protozoan	Chrysococcidae	ES
Monas guttula	chrysomonad protozoan	Ochromonadidae	ES
Monas socialis	chrysomonad protozoan	Ochromonadidae	ES
Ochromonas ludibunda	chrysomonad protozoan	Ochromonadidae	ES
Oikomonas termo	chrysomonad protozoan	Chromulinidae	ES
Physomonas vestita	chrysomonad protozoan	Ochromonadidae	ES
Spumella sp.	chrysomonad protozoan	Ochromonadidae	ES
Stokesiella sp.	chrysomonad protozoan	Dinobryonidae	ES
Order Volvocida			
Carteria globosa	volvocean protozoan	Carteriidae	ES
Chlamydomonas excavata	volvocean protozoan	Chlamydomonadidae	ES
Chlamydomonas globosa	volvocean protozoan	Chlamydomonadidae	ES
Chlamydomonas gracilis	volvocean protozoan	Chlamydomonadidae	ES
Chlamydomonas monadina	volvocean protozoan	Chlamydomonadidae	ES
Chlamydomonas reinhardtii	volvocean protozoan	Chlamydomonadidae	ES
Chlamydomonas subasymmetrica	volvocean protozoan	Chlamydomonadidae	ES
Chlorogonium elongatum	volvocean protozoan	Chlamydomonadidae	ES
Chlorogonium euchlorum	volvocean protozoan	Chlamydomonadidae	ES
Chlorogonium hyalinum	volvocean protozoan	Chlamydomonadidae	ES
Pandorina morum	volvocean protozoan	Volvocidae	ES
Phacotus lenticularis	volvocean protozoan	Phacotidae	ES
Pteromonas sp.	volvocean protozoan	Phacotidae	ES

	Common Name	Family	Location
CLASS EUGLENEA			
Order Euglenida (green euglenas)			
Ascoglena vaginicola?	euglenoid protozoan	Trachelomonadidae	ES
Astasia klebsii	euglenoid protozoan	Euglenidae	ES
Euglena acus	euglenoid protozoan	Euglenidae	ES
Euglena deses	euglenoid protozoan	Euglenidae	ES
Euglena ehrenbergii	euglenoid protozoan	Euglenidae	ES
Euglena gracilis	euglenoid protozoan	Euglenidae	ES
Euglena oxyuris	euglenoid protozoan	Euglenidae	ES
Euglena oxyuris var. *minor*	euglenoid protozoan	Euglenidae	ES
Euglena pisciformis	euglenoid protozoan	Euglenidae	ES
Euglena tripteris	euglenoid protozoan	Euglenidae	ES
Euglena vermiforis	euglenoid protozoan	Euglenidae	ES
Lepocinclis sp.	euglenoid protozoan	Euglenidae	ES
Menoidium gibbum	euglenoid protozoan	Euglenidae	ES
Phacus acuminatus	euglenoid protozoan	Euglenidae	ES
Phacus arnoldi	euglenoid protozoan	Euglenidae	ES
Phacus helikoides	euglenoid protozoan	Euglenidae	ES
Phacus pleuronectes	euglenoid protozoan	Euglenidae	ES
Phacus pseudoonordstedii	euglenoid protozoan	Euglenidae	ES
Phacus tortus	euglenoid protozoan	Euglenidae	ES
Rhabdomonas sp.	euglenoid protozoan	Euglenidae	ES
Scytomonas sp.	euglenoid protozoan	Euglenidae	ES
Strombomonas gibberosa	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas armata	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas hispida	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas horrida	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas spiralis	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas superba	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas varians	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas volvocina	euglenoid protozoan	Trachelomonadidae	ES
Trachelomonas volvocina var. *minuta*	euglenoid protozoan	Trachelomonadidae	ES
Urceolus ovatus	euglenoid protozoan	Trachelomonadidae	ES
Urceolus sabulosus	euglenoid protozoan	Trachelomonadidae	ES
Order Peranemida (colorless euglenas)			
Anisonema acinus	colorless euglena	Anisonemidae	ES
Anisonema emarginatum	colorless euglena	Anisonemidae	ES
Anisonema ovale	colorless euglena	Anisonemidae	ES
Anisonema strenuum	colorless euglena	Anisonemidae	ES
Anisonema truncatum	colorless euglena	Anisonemidae	ES
Entosiphon obliquum	colorless euglena	Anisonemidae	ES
Entosiphon ovatum	colorless euglena	Anisonemidae	ES
Entosiphon polyalux	colorless euglena	Anisonemidae	ES
Entosiphon sulcatum	colorless euglena	Anisonemidae	ES
Heteronema klebsii	colorless euglena	Peranemidae	ES
Notosolenus apocamptus	colorless euglena	Anisonemidae	ES
Notosolenus obicularis	colorless euglena	Anisonemidae	ES
Notosolenus sinuatus	colorless euglena	Anisonemidae	ES
Peranema asperum	colorless euglena	Peranemidae	ES
Peranema inflexum	colorless euglena	Peranemidae	ES
Peranema trichophorum	colorless euglena	Peranemidae	ES
Petalomonas mediocanella	colorless euglena	Petalomonadidae	ES
Petalomonas minuta	colorless euglena	Petalomonadidae	ES
Petalomonas quadrilineata	colorless euglena	Petalomonadidae	ES
CLASS ZOOMASTIGOPHORA			
Order Choanoflagellida			
Codonosiga sp.?	choanoflagellate	Codonosigidae	ES
Codonosigopsis sp.	choanoflagellate	Codonosigidae	ES
Codosiga sp.	choanoflagellate	Codonosigidae	ES
Desmarella sp.	choanoflagellate	Codonosigidae	ES

Order Choanoflagellida (cont'd)	Common Name	Family	Location
Diplosiga sp.	choanoflagellate	Codonosigidae	ES
Monosiga ovata	choanoflagellate	Codonosigidae	ES
Monosiga robusta	choanoflagellate	Codonosigidae	ES
Poteriodendron petiolatum	choanoflagellate	Salpingoecidae	ES
Salpingoeca elegans	choanoflagellate	Salpingoecidae	ES
Order Kinetoplastida			
Bodo alexeieffii	kinetoplastid protozoan	Bodonidae	ES
Bodo amoebinus	kinetoplastid protozoan	Bodonidae	ES
Bodo angustus [=*Bodo saliens*]	kinetoplastid protozoan	Bodonidae	ES
Bodo caudatus	kinetoplastid protozoan	Bodonidae	ES
Bodo celer	kinetoplastid protozoan	Bodonidae	ES
Bodo edax	kinetoplastid protozoan	Bodonidae	ES
Bodo fusiformis	kinetoplastid protozoan	Bodonidae	ES
Bodo globosa	kinetoplastid protozoan	Bodonidae	ES
Bodo minimus	kinetoplastid protozoan	Bodonidae	ES
Bodo obovatus	kinetoplastid protozoan	Bodonidae	ES
Bodo ovatus	kinetoplastid protozoan	Bodonidae	ES
Bodo repens	kinetoplastid protozoan	Bodonidae	ES
Bodo rostratus	kinetoplastid protozoan	Bodonidae	ES
Bodo saltans	kinetoplastid protozoan	Bodonidae	ES
Bodo triangularis	kinetoplastid protozoan	Bodonidae	ES
Bodo uncinatus	kinetoplastid protozoan	Bodonidae	ES
Bodo variabilis	kinetoplastid protozoan	Bodonidae	ES
Cercobodo sp.	kinetoplastid protozoan	Bodonidae	ES
Cercomonas crassicauda	kinetoplastid protozoan	Bodonidae	ES
Cercomonas longicauda	kinetoplastid protozoan	Bodonidae	ES
Colponema loxodes	kinetoplastid protozoan	Bodonidae	ES
Pleuromonas jaculans	kinetoplastid protozoan	Bodonidae	ES
Rhynchomonas nasuta	kinetoplastid protozoan	Bodonidae	ES
	Subphylum Sarcodina		
CLASS LOBOSA			
Order Amoebida			
Amoeba sp.	amoeboid protozoan	Amoebidae	ES
Cashia limacoides	amoeboid protozoan	Hartmannellidae	ES
Centropyxis sp.	amoeboid protozoan	Centropyxidae	ES
Hartmannella vermiformis	amoeboid protozoan	Hartmannellidae	ES
Hartmannella sp.	amoeboid protozoan	Hartmannellidae	ES
Mayorella bigemma	amoeboid protozoan	Paramoebidae	ES
Mayorella penardi	amoeboid protozoan	Paramoebidae	ES
Oscillosignum proboscidium	amoeboid protozoan	Paramoebidae	ES
Striamoeba quadrilineata	amoeboid protozoan	Thecamoebidae	ES
Striamoeba sp.	amoeboid protozoan	Thecamoebidae	ES
Thecamoeba striata	amoeboid protozoan	Thecamoebidae	ES
Trichamoeba sp.	amoeboid protozoan	Amoebidae	ES
Vannella miroides	amoeboid protozoan	Thecamoebidae	ES
Vexillifera sp.	amoeboid protozoan	Paramoebidae	ES
Order Schizopyrenida			
Naegleria gruber	amoeboid protozoan	Vahlkampfiidae	ES
Vahlkampfia sp.	amoeboid protozoan	Vahlkampfiidae	ES
Order Pelobiotida			
Pelomyxa sp.	amoeboid protozoan	Pelomyxidae	ES
Order Arcellinida			
Arcella discoides	amoeboid protozoan	Arcellidae	ES
Arcella vulgaris	amoeboid protozoan	Arcellidae	ES
Cochliopodium bilimbosum	amoeboid protozoan	Cochliopodiidae	ES
Cochliopodium minus	amoeboid protozoan	Cochliopodiidae	ES
Difflugia acuminata	amoeboid protozoan	Difflugiidae	ES

Order Arcellinida (cont'd)	Common Name	Family	Location
Difflugia globosa	amoeboid protozoan	Difflugiidae	ES
Difflugia lobostoma	amoeboid protozoan	Difflugiidae	ES
Difflugia pyriformis	amoeboid protozoan	Difflugiidae	ES
Hyalosphenia sp.	amoeboid protozoan	Arcellidae	ES
Pseudodifflugia sp.	amoeboid protozoan	Difflugiidae	ES
CLASS FILOSA			
Order Aconchulinida			
Nuclearia sp.	amoeboid protozoan	Vampyrellidae	ES
Vampyrella lateritia	amoeboid protozoan	Vampyrellidae	ES
Order Testaceafilosida			
Cyphoderia ampulla	amoeboid protozoan	Cyphoderiidae	ES
CLASS GRANULORETICULOSA			
Order Athalamida			
Biomyxa vagans	amoeboid protozoan	Biomyxidae	ES
Order Foraminiferida			
Diplophrys archeri	amoeboid protozoan	Lagynidae	ES
CLASS HELIOZOA			
Order Actinophryida			
Actinophrys sol	heliozoan	Actinophryidae	ES
Actinophrys vesiculata	heliozoan	Actinophryidae	ES
Actinosphaerium sp.	heliozoan	Actinosphaeridae	ES
Ciliophrys sp.	heliozoan	Ciliophryidae	ES
Order Centrohelida			
Acanthocystis aculeata	heliozoan	Acanthocystidae	ES
Acanthocystis chaetophora	heliozoan	Acanthocystidae	ES
Acanthocystis mira	heliozoan	Acanthocystidae	ES
Acanthocystis myriospina	heliozoan	Acanthocystidae	ES
Acanthocystis turfacea	heliozoan	Acanthocystidae	ES
Heterophrys sp.	heliozoan	Heterophryidae	ES
Pompholyxophrys sp.	heliozoan	Acanthocystidae	ES
Raphidiocystis sp.	heliozoan	Acanthocystidae	ES
Raphidiophrys pallida	heliozoan	Raphidiophryidae	ES
Raphidiophrys sp.	heliozoan	Raphidiophryidae	ES
PHYLUM CILIOPHORA (PROTOZOA)			
CLASS KINETOFRAGMINOPHORA			
Order Prostomatida			
Balanion sp.	ciliated protozoan	Holophryidae	ES
Coleps bicuspis	ciliated protozoan	Colepidae	ES
Coleps hirtus	ciliated protozoan	Colepidae	ES
Coleps octospinus	ciliated protozoan	Colepidae	ES
Holophrya nigricans	ciliated protozoan	Holophryidae	ES
Holophrya sp.	ciliated protozoan	Holophryidae	ES
Placus ovum	ciliated protozoan	Prorodontidae	ES
Prorodon discolor	ciliated protozoan	Prorodontidae	ES
Urotricha armata	ciliated protozoan	Prorodontidae	ES
Urotricha farcta	ciliated protozoan	Prorodontidae	ES
Urotricha furcata	ciliated protozoan	Prorodontidae	ES
Order Haptorida			
Askenasia volvox	ciliated protozoan	Didiniidae	ES
Chaenea sp.	ciliated protozoan	Enchelyidae	ES
Didinium nasutum	ciliated protozoan	Didiniidae	ES
Enchelydium sp.	ciliated protozoan	Spathidiidae	ES
Lacrymaria olor	ciliated protozoan	Enchelyidae	ES
Mesodinium pulex	ciliated protozoan	Didiniidae	ES
Trachelius ovum	ciliated protozoan	Tracheliidae	ES

Order Haptorida (cont'd)	Common Name	Family	Location
Trachelophyllum pusillum	ciliated protozoan	Enchelyidae	ES
Trachelophyllum sigmoides	ciliated protozoan	Enchelyidae	ES
Order Pleurostomatida			
Acineria incurvata	ciliated protozoan	Amphileptidae	ES
Hemiophrys pleurosigma	ciliated protozoan	Amphileptidae	ES
Hemiophrys sp.	ciliated protozoan	Amphileptidae	ES
Litonotus anguilla	ciliated protozoan	Amphileptidae	ES
Litonotus cygus	ciliated protozoan	Amphileptidae	ES
Litonotus fasciola	ciliated protozoan	Amphileptidae	ES
Litonotus lamella	ciliated protozoan	Amphileptidae	ES
Litonotus sp.	ciliated protozoan	Amphileptidae	ES
Loxophyllum uninucleatum	ciliated protozoan	Amphileptidae	ES
Loxophyllum sp.	ciliated protozoan	Amphileptidae	ES
Order Colpodida			
Cyrtolophosis mucicola	ciliated protozoan	Cyrtolophosidiidae	ES
Order Nassulida			
Chilodontopsis opsis	ciliated protozoan	Nassulidae	ES
Leptopharynx sphagnetorum	ciliated protozoan	Leptopharyngidae	ES
Microthorax simulans	ciliated protozoan	Microthoracidae	ES
Trichopelma sp.	ciliated protozoan	Leptopharyngidae	ES
Order Cyrtophorida			
Chilodonella acuta	ciliated protozoan	Chilodonellidae	ES
Chilodonella algivora	ciliated protozoan	Chilodonellidae	ES
Chilodonella capucina	ciliated protozoan	Chilodonellidae	ES
Chilodonella labiata	ciliated protozoan	Chilodonellidae	ES
Chilodonella nana	ciliated protozoan	Chilodonellidae	ES
Chilodonella uncinata	ciliated protozoan	Chilodonellidae	ES
Trochilia palustris	ciliated protozoan	Dysteriidae	ES
Trochilia pusillum	ciliated protozoan	Dysteriidae	ES
Trochilia sigmoides	ciliated protozoan	Dysteriidae	ES
Order Suctorida			
Acineta tuberosa	ciliated protozoan	Acinetidae	ES
Sphaerophrya sp.	ciliated protozoan	Podophryidae	ES
Tokophrya sp.	ciliated protozoan	Dendrosomatidae	ES
CLASS OLIGOHYMENOPHORA			
Order Hymenostomatida			
Frontonia sp.	ciliated protozoan	Frontoniidae	ES
Lembadion bullinum	ciliated protozoan	Lembadionidae	ES
Paramecium caudatum	ciliated protozoan	Parameciidae	ES
Tetrhymena pyriformis	ciliated protozoan	Tetrahymenidae	ES
Urocentrum turbo	ciliated protozoan	Urocentridae	ES
Order Scuticociliatida			
Calyptotricha pleuronemoides	ciliated protozoan	Pleuronematidae	ES
Cinetochilum margaritaceum	ciliated protozoan	Cinetochilidae	ES
Cristigera phoenix	ciliated protozoan	Cyclidiida	ES
Cyclidium glaucoma	ciliated protozoan	Cyclidiida	ES
Cyclidium litomesum	ciliated protozoan	Cyclidiida	ES
Cyclidium muscicola	ciliated protozoan	Cyclidiida	ES
Cyclidium paucisetum	ciliated protozoan	Cyclidiida	ES
Cyclidium pellucidum	ciliated protozoan	Cyclidiida	ES
Cyclidium versatile	ciliated protozoan	Cyclidiida	ES
Histiobalantium natans	ciliated protozoan	Histiobalantidiidae	ES
Pleuronema sp.	ciliated protozoan	Pleuronematidae	ES
Uromema sp.	ciliated protozoan	Uronematidae	ES

Order Peritrichida (stalked ciliates)	Common Name	Family	Location
Vaginicola sp.	stalked ciliated protozoan	Vaginicolidae	ES
Vorticella campanula	stalked ciliated protozoan	Vorticellidae	ES
Vorticella microstoma	stalked ciliated protozoan	Vorticellidae	ES
Vorticella picta	stalked ciliated protozoan	Vorticellidae	ES
Vorticella striata	stalked ciliated protozoan	Vorticellidae	ES
Zoothamnium sp.	stalked ciliated protozoan	Vorticellidae	ES
CLASS POLYHYMENOPHORA			
Order Heterotrichida			
Spirostromum sp.	ciliated protozoan	Spirostomidae	ES
Stentor sp.	ciliated protozoan	Stentoridae	ES
Order Oligotrichida			
Codonella cratera	ciliated protozoan	Codonellidae	ES
Halteria grandunella	ciliated protozoan	Halteriidae	ES
Limnostrombidium sp.	ciliated protozoan	Strombidiidae	ES
Pelagostrombidium fallax	ciliated protozoan	Strombidiidae	ES
Rimostrombidium humile	ciliated protozoan	Strombidiidae	ES
Rimostrombidium lacustris	ciliated protozoan	Strombidiidae	ES
Strobilidium gyrans	ciliated protozoan	Strombilidiidae	ES
Tintinnidium fluviatile	ciliated protozoan	Tintinnidae	ES
Order Hypotrichida			
Aspidisca costata	ciliated protozoan	Aspidiscidae	ES
Aspidisca lynceus	ciliated protozoan	Aspidiscidae	ES
Aspidisca steini	ciliated protozoan	Aspidiscidae	ES
Balladyna fusiformis	ciliated protozoan	Holostichidae	ES
Balladyna ovata	ciliated protozoan	Holostichidae	ES
Balladyna parvula	ciliated protozoan	Holostichidae	ES
Euplotes sp.	ciliated protozoan	Euplotidae	ES
Holostricha vernalis	ciliated protozoan	Holostichidae	ES
Hypotrichidium conicum	ciliated protozoan	Spirofilida	ES
Keronopsis sp.	ciliated protozoan	Holostichidae	ES
Oxytricha aeruginosa	ciliated protozoan	Oxytrichidae	ES
Oxytricha bifaria	ciliated protozoan	Oxytrichidae	ES
Oxytricha chlorelligeum	ciliated protozoan	Oxytrichidae	ES
Oxytricha setigera	ciliated protozoan	Oxytrichidae	ES
Oxytricha tricornis	ciliated protozoan	Oxytrichidae	ES
Stichotricha secunda	ciliated protozoan	Strongylidiidae	ES
Stylonychia mytilus	ciliated protozoan	Oxytrichidae	ES
Stylonychia notophora	ciliated protozoan	Oxytrichidae	ES
Tachysoma pellionella	ciliated protozoan	Oxytrichidae	ES
Tachysoma sp.	ciliated protozoan	Oxytrichidae	ES
Uroleptus sp.	ciliated protozoan	Holostichidae	ES
Urostyla grandis	ciliated protozoan	Strongylidiidae	ES
Urostyla sp.	ciliated protozoan	Strongylidiidae	ES
	PHYLUM PORIFERA		
CLASS DEMOSPONGIAE (horny sponges)			
Order Haplosclerida			
Eunapius fragilis	freshwater sponge	Spongillidae	LE

PHYLUM CNIDARIA [=COELENTERATA]

CLASS HYDROZOA (hydras)			
Order Hydroida			
Hydra americana	hydra	Hydridae	ES
Order Trachylina			
Craspedacusta sowerbyi	freshwater jellyfish	Petasidae	CK,TR

	Common Name	Family	Location
	PHYLUM PLATYHELMINTHES		
CLASS TURBELLARIA (flatworms)			
Order Catenulida (catenulids)			
Stenostomum sp.	turbellarian flatworm	Stenostomidae	ES
Order Neorhabdocoela			
Microdalyellia sp.?	turbellarian flatworm	Dalyellioda	ES
Mesostoma sp.?	turbellarian flatworm	Typhloplanidae	ES
Order Tricladida (planarians)			
Dugesia tigrina	planaria	Planariidae	CK
Hymanella retenuova	planaria	Planariidae	ES
	PHYLUM GASTROTRICHA		
Order Chaetonotida (gastrotrichs)			
Chaetonotus sp.	gastrotrich	Chaetonotidae	ES
	PHYLUM ROTIFERA		
CLASS BDELLOIDEA (rotifers)			
Order Bdelloida			
Philodina sp.	rotifer	Philodinidae	ES
Rotaria neptunia	rotifer	Philodinidae	ES
CLASS MONOGONONTA (rotifers)			
Order Ploima			
Ascomorpha ecaudis	rotifer	Gastropodidae	ES
Asplanchna priodonta	rotifer	Asplanchnidae	ES
Brachionus angularis	rotifer	Brachionidae	ES
Brachionus bidentata	rotifer	Brachionidae	ES
Brachionus calyciiflorus	rotifer	Brachionidae	ES
Brachionus caudatus	rotifer	Brachionidae	ES
Brachionus havanaensis	rotifer	Brachionidae	ES
Brachionus quadridentatus	rotifer	Brachionidae	ES
Brachionus urceolaris	rotifer	Brachionidae	ES
Euchlanis parva	rotifer	Brachionidae	ES
Kellicottia longispina	rotifer	Brachionidae	ES
Keratella cochlearis	rotifer	Brachionidae	ES
Keratella cochlearis forma *tecta*	rotifer	Brachionidae	ES
Keratella cochlearis forma *typica*	rotifer	Brachionidae	ES
Keratella quadrata	rotifer	Brachionidae	ES
Lecane luna	rotifer	Lecanidae	ES
Platyias patulus	rotifer	Brachionidae	ES
Ploesoma hudsoni	rotifer	Synchaetidae	ES
Polyarthra dolichoptera	rotifer	Synchaetidae	ES
Polyarthra remata	rotifer	Synchaetidae	ES
Sychaeta kitina	rotifer	Synchaetidae	ES
Sychaeta stylata	rotifer	Synchaetidae	ES
Trichocerca multicrinis	rotifer	Trichocercidae	ES
Trichotria tetractis	rotifer	Brachionidae	ES
Order Flosclaricea (rotifers)			
Conochilus sp.	rotifer	Conochilidae	LE
Filinia sp.	rotifer	Testudinellidae	ES
Floscularia sp.	rotifer	Flosculariidae	ES
Sinantherina sp.	rotifer	Flosculariidae	ES
	PHYLUM NEMATODA		
CLASS ADENOPHOREA (roundworms)			
Order Enoplida			
Tobrilus sp.	roundworm	Tripylidae	ES

	Common Name	Family	Location
Order Dorylaimida			
Dorylaimus sp.	roundworm	Dorylaimidae	ES
Order Tylenchida			
Criconemoides sp.	roundworm	Criconematidae	ES
	PHYLUM MOLLUSCA		
CLASS GASTROPODA (snails)			
Order Mesogastropoda			
Cipangopaludina japonicus	Japanese mystery snail	Viviparidae	ES
Order Basommatophora (freshwater snails)			
Ferrissia parallela	oblong ancylid	Ancylidae	ES
Fossaria sp. [=*Galba* sp.]	fossaria	Lymnaeidae	ES
Gyraulus deflectus	flexed gyro	Planorbidae	ES
Helisoma anceps anceps	two-ridge rams-horn	Planorbidae	ES
Lymnaea megasoma [=*Bulimnaea m.*]	mammoth lymnaea	Lymnaeidae	ES
Physa sp.	physa	Physidae	ES
Physella gyrina	tadpole physa	Physidae	ES
Pseudosuccinea columella	mimic lymnaea	Lymnaeidae	ES
Order Stylommatophora (land snails)			
Mesodon thyroidus	white-lip globe	Polygyridae	ES
CLASS BIVALVIA (clams)			
Order Unionoida			
Amblema plicata plicata	threeridge	Unionoidae	LE
Anodontoides ferussacianus	cylindrical papershell	Unionoidae	TR
Cyclonaias tuberculata	purple wartyback	Unionoidae	LE
Elliptio dilatata	spike	Unionoidae	LE,TR
Lampsilis radiata luteola	lampmussel	Unionoidae	LE,TR
Lampsilis ventricosa	fatmucket	Unionoidae	LE,TR
Lasmigona compressa	creek heelsplitter	Unionoidae	TR
Leptodea fragilis	fragile papershell	Unionoidae	LE
Ligumia recta	black sandshell	Unionoidae	LE
Potamilus alatus	pink heelsplitter	Unionoidae	ES,LE
Pyganodongrandis grandis	giant floater	Unionoidae	ES,LE
Ptychobranchus fasciolaris	kidneyshell	Unionoidae	LE
Quadrula pustulosa pistulosa	pimpleback	Unionoidae	LE
Toxolasma parvus	lilliput	Unionoidae	LE
Truncilla donaciformis	fawnsfoot	Unionoidae	LE
Truncilla truncilla	deertoe	Unionoidae	LE
Utterbackia imbecillis	paper pondshell	Unionoidae	ES,LE
Order Veneroida			
Dreissena bugensis	quagga mussel	Dreissenidae	LE
Dreissena polymorpha	zebra mussel	Dreissenidae	ES,LE
Musculium securis [=*Sphaerium securis*]	pond fingernail clam	Pisidiidae	ES
Musculium sp.	fingernail clam	Pisidiidae	ES
Pisiddium compressum	ridge-beak peaclam	Pisidiidae	ES
	PHYLUM ANNELIDA		
CLASS HIRUDINEA (leeches)			
Order Rhynochobdella			
Batracobdella phalera	leech	Glossiphoniidae	ES
Glossiphonia sp.	leech	Glossiphoniidae	ES
Helobdella stagnalis	leech	Glossiphoniidae	ES
Placobdella sp.	leech	Glossiphoniidae	ES
CLASS OLIGOCHAETA (segmented worms)			
Order Lumbriculida			
Lumbriculus variegatus	aquatic earthworm	Lumbriculidae	ES
Stylodrillus heringianus	aquatic earthworm	Lumbriculidae	ES

Order Haplotaxida	Common Name	Family	Location
Aeolosoma headleyi	aquatic earthworm	Aeolosomatidae	ES
Aeolosoma hemprichi	aquatic earthworm	Aeolosomatidae	ES
Amphichaeta leydigii	naidid worm	Naididae	ES
Aulodrilus limnobius	tubificid worm	Tubificidae	ES
Aulodrilus pigueti	tubificid worm	Tubificidae	ES
Aulodrilus pluriseta	tubificid worm	Tubificidae	ES
Branchirua sowerbyi	tubificid worm	Tubificidae	ES
Chaetogaster diaphanus	naidid worm	Naididae	ES
Chaetogaster diastrophus?	naidid worm	Naididae	ES
Chaetogaster limnaei	naidid worm	Naididae	ES
Dero nivea	naidid worm	Naididae	ES
Dero trifida?	naidid worm	Naididae	ES
Dero vaga [=*Auloporus vaga*]	naidid worm	Naididae	ES
Haemonais waldvogeli	naidid worm	Naididae	ES
Ilyodrilus templetoni	tubificid worm	Tubificidae	ES
Limnodrilius hoffmeisteri	tubificid worm	Tubificidae	ES
Limnodrilius maumeensis	tubificid worm	Tubificidae	ES
Limnodrilius profundicola	tubificid worm	Tubificidae	ES
Limnodrilius udekemianus	tubificid worm	Tubificidae	ES
Limnodrilius cervix	tubificid worm	Tubificidae	ES
Limnodrilius claparedeianus	tubificid worm	Tubificidae	ES
Nais barbata	naidid worm	Naididae	ES
Nais communis	naidid worm	Naididae	ES
Nais elinguis	naidid worm	Naididae	ES
Nais pardalis	naidid worm	Naididae	ES
Nais pseudobtusa	naidid worm	Naididae	ES
Nais variabilis	naidid worm	Naididae	ES
Ophidonais serpentina	naidid worm	Naididae	ES
Pristina longiseta longiseta	naidid worm	Naididae	ES
Pristina sima?	naidid worm	Naididae	ES
Pristinaella osborni	naidid worm	Naididae	ES
Pristinella acuminata?	naidid worm	Naididae	ES
Pristinella jenkinae	naidid worm	Naididae	ES
Quistadrilus multisetosus	tubificid worm	Tubificidae	ES
Rhyacodrilus coccineus	tubificid worm	Tubificidae	ES
Telmatodrilus sp.?	tubificid worm	Tubificidae	ES
Vejdovskyella comata	naidid worm	Naididae	ES
Vejdovskyella intermedia	naidid worm	Naididae	ES
	PHYLUM ARTHROPODA		
CLASS ARACHNIDA			
Order Araneae (spiders)			
Achaearanea tepidariorum	American house spider	Theridiidae	CK
Agelenopsis pennsylvanica	green spider	Agelenidae	CK
Agroeca pratensis?	sac spider	Clubionidae	ES
Allocosa funerea	wolf spider	Lycosidae	CK
Alopecosa aculeata?	wolf spider	Lycosidae	CK
Anyphaena celer	hunting spider	Anyphaenidae	CK
Araneus marmoreus	marbled orb weaver	Araneidae	CK
Araneus trifolium	orb weaver	Araneidae	CK
Argiope aurantia	black & yellow garden spider	Araneidae	CK
Argiope trifasciata	banded garden	Araneidae	CK
Atopogyna cornupalis	sheet-web weaver	Linyphiidae	CK
Bathyphantes sp.?	sheet-web weaver	Linyphiidae	CK
Callobius sp.?	thread-web weaver	Amaurobiidae	CK
Castianeira cingulata	sac spider	Clubionidae	CK
Ceraticelus fissiceps	dwarf spider	Linyphiidae	CK
Cheiracanthium mildei	sac spider	Clubionidae	CK
Cicurina pallida	loose-web weaver	Dictynidae	CK
Cirurina robusta	funnel web weaver	Agelenidae	CK

Order Araneae (cont'd)	Common Name	Family	Location
Clubiona sp.	sac spider	Clubionidae	CK
Clubionoides excepta?	sac spider	Clubionidae	CK
Coras medicinalis	funnel web weaver	Agelenidae	CK
Coriarachne versicolor?	crab spider	Thomisidae	CK
Crustulina altera	comb-footed spider	Theridiidae	CK
Cyclosa conica	orb weaver	Araneidae	CK
Dictynia annulipes	loose-web weaver	Dictynidae	CK
Dolomedes tenebrosus?	nursery web spider	Pisauridae	CK
Eris militaris	jumping spider	Salticidae	CK
Ero canionis	ambush spider	Mimetidae	ES
Eustala anastera	orb weaver	Araneidae	CK
Frontinella pyramitela	sheet-web weaver	Linyphiidae	CK
Gea heptagon	orb weaver	Araneidae	CK
Habrocestum pulex	jumping spider	Salticidae	CK
Herpyllus ecclesiasticus	parson spider	Gnaphosidae	CK
Hogna helluo	wolf spider	Lycosidae	ES
Hogna rabida	wolf spider	Lycosidae	ES
Lepthyphantes zebra	sheet-web weaver	Linyphiidae	CK
Maevia inclemens?	jumping spider	Salticidae	CK
Mangora placida	orb weaver	Araneidae	CK
Meioneta unimaculata	sheet-web weaver	Linyphiidae	CK
Metaphidippus sp.	jumping spider	Salticidae	CK
Micrathena gracilis	orb weaver	Araneidae	CK
Misumenoides formosipes	crab spider	Thomisidae	CK
Misumenops asperatus?	crab spider	Thomisidae	CK
Neoscona crucifera	orb weaver	Araneidae	CK
Neriene radiata? [or *Microlin* sp.]	sheet-web weaver	Linyphiidae	CK
Pardosa milvina	wolf spider	Lycosidae	CK
Pardosa moesta?	thin-legged wolf spider	Lycosidae	CK
Pardosa saxatilis	wolf spider	Lycosidae	ES
Phidippus audax	jumping spider	Salticidae	CK
Phidippus clarus	jumping spider	Salticidae	CK
Phidippus whitmani	jumping spider	Salticidae	CK
Philodromus keyserlingi	crab spider	Thomisidae	CK
Philodromus vulgaris	crab spider	Thomisidae	CK
Pholcus phalangioides	cellar spider	Pholcidae	CK
Pirata minutus?	wolf spider	Lycosidae	CK
Pisaurina mira	nursery web spider	Pisauridae	CK
Pityohyphantes costatus	hammock spider	Linyphiidae	CK
Platycryptus undatus	jumping spider	Salticidae	CK
Salticus scenicus	jumping spider	Salticidae	CK
Schizocosa avida	wolf spider	Lycosidae	CK
Schizocosa ocreata	wolf spider	Lycosidae	CK
Sitticus sp.	jumping spider	Salticidae	CK
Steatoda borealis	comb-footed spider	Theridiidae	CK
Steatoda triangulosa	comb-footed spider	Theridiidae	CK
Tetragnatha elongata	stilt-legged spider	Tetragnathidae	CK
Tetragnatha laboriosa	long-jawed orb weaver	Tetragnathidae	CK
Theridion frondeum	comb-footed spider	Theridiidae	CK
Tmarus angulatus	crab spider	Thomisidae	CK
Trachelas tranquillus	sac spider	Clubionidae	CK
Tutelina elegans	jumping spider	Salticidae	CK
Verrucosa arenata	orb weaver	Araneidae	CK
Xysticus elegans	crab spider	Thomisidae	CK
Xysticus ferox	crab spider	Thomisidae	CK
Xysticus funestus	crab spider	Thomisidae	CK
Order Acariformes (mites)			
Limnesia sp.	freshwater mite	Limnessiidae	ES
Neumania sp.	clam mite	Unionicolidae	ES
Unionicola sp.	clam mite	Unionicolidae	ES

CLASS CRUSTACEA (crustaceans) Subclass Branchiopoda Order Cladocera (water fleas)	Common Name	Family	Location
Alona barbulata?	water flea	Chydoridae	CK,ES
Alona cf. *circumfimbriata*	water flea	Chydoridae	CK
Alona costata	water flea	Chydoridae	ES
Alona guttata	water flea	Chydoridae	ES
Alona quadrangularis	water flea	Chydoridae	CK,ES,LE
Alonella excisa [or *Alonella exigua*?]	water flea	Chydoridae	ES
Alonella hamulata	water flea	Chydoridae	CK,ES
Alonella nana	water flea	Chydoridae	ES
Alonella setulosa	water flea	Chydoridae	ES,LE
Bosmina longirostris	water flea	Bosminidae	ES
Bythotrephes cederstroemi	spiny water flea	Cercopagidae	LE
Ceriodaphnia lacustris	water flea	Daphnidae	CK,ES
Ceriodaphnia quadrangula	water flea	Daphnidae	ES
Ceriodaphnia reticulata	water flea	Daphnidae	ES
Chydorus sphaericus	water flea	Chydoridae	ES
Daphnia catawba	water flea	Daphnidae	LE
Daphnia galeata mendotae	water flea	Daphnidae	CK,ES,LE
Daphnia parvula	water flea	Daphnidae	CK,LE
Daphnia retrocurva	water flea	Daphnidae	CK,ES,LE
Diaphanosoma birgei	water flea	Sididae	CK,ES,LE
Disparalona leei	water flea	Chydoridae	CK,ES,LE
Eubosmina coregoni [=*Bosmina coregoni*]	water flea	Bosminidae	CK,ES,LE
Ilyocryptus sordidus	water flea	Macrothricidae	CK,ES,LE
Latona setifera	water flea	Sididae	ES
Leptodora kindtii	large water flea	Leptodoridae	LE
Leydigia acanthocercoides	water flea	Chydoridae	ES
Leydigia leydigi	water flea	Chydoridae	CK,ES,LE
Macrothrix laticornis	water flea	Macrothricidae	CK,ES
Moina micrura	water flea	Moinidae	CK,ES
Pleuroxus cf. *denticulatus*	water flea	Chydoridae	CK,ES
Pleuroxus procurvus	water flea	Chydoridae	CK,ES
Pseudochydorus globosus	water flea	Chydoridae	CK,ES
Scapholeberis kingi	water flea	Daphnidae	ES
Scapholeberis mucronata	water flea	Daphnidae	ES
Sida crystallina	water flea	Sididae	ES
Simocephalus serrulatus	water flea	Daphnidae	CK,ES
Subclass Ostracoda (seed shrimps)			
Order Podocopina			
Candona simpsoni	seed shrimp	Candonidae	ES
Cypria maculata	seed shrimp	Cyprididae	ES
Cypria ophthalmica	seed shrimp	Cyprididae	ES
Cypria pellucida	seed shrimp	Cyprididae	ES
Cypridopsis vidua	seed shrimp	Cypridopsidae	ES
Darwinula stevensoni	seed shrimp	Darwinulidae	ES
Pelocypris sp.	seed shrimp	Ilyocyprididae	ES
Physocypria pustulosa	seed shrimp	Cyprididae	ES
Subclass Copepoda (copepods)			
Order Calanoida			
Diaptomus sp.	copepod	Diaptomidae	ES
Epischura lacustris	copepod	Temoridae	ES
Eurytemora affinis	copepod	Temoridae	CK,ES,LE
Leptodiaptomus ashlandi	copepod	Diaptomidae	CK,ES,LE
Leptodiaptomus minutus	copepod	Diaptomidae	ES,LE
Leptodiaptomus sicilis	copepod	Diaptomidae	ES,LE
Leptodiaptomus siciloides	copepod	Diaptomidae	CK,ES,LE
Skistodiaptomus oregonesis	copepod	Diaptomidae	CK,ES,LE
Skistodiaptomus pallidus	copepod	Diaptomidae	CK,ES

Order Cyclopoida	**Common Name**	**Family**	**Location**
Acanthocyclops vernalis sensu lata	copepod	Cyclopidea	CK,ES,LE
Cyclops varicans rubellus?	copepod	Cyclopidea	CK,ES,LE
Diacyclops cf. *navus*	copepod	Cyclopidea	ES
Diacyclops nearcticus	copepod	Cyclopidea	ES
Diacyclops thomasi	copepod	Cyclopidea	CK,ES,LE
Eucyclops agilis	copepod	Cyclopidea	ES,LE
Eucyclops elegans [=*E. speratus*]	copepod	Cyclopidea	ES
Macrocyclops albidus	copepod	Cyclopidea	ES
Mesocyclops edax	copepod	Cyclopidea	CK,ES,LE
Microcyclops varicans rubellus	copepod	Cyclopidea	ES
Paracyclops fimbriatus poppei	copepod	Cyclopidea	ES
Tropocyclops prasinus mexicanus	copepod	Cyclopidea	CK,ES,LE
Order Harpacticoida			
Attheyella illinoisensis	copepod	Canthocamptidae	ES
Bryocamptus sp.	copepod	Canthocamptidae	ES
Canthocamptus robertcokeri	copepod	Canthocamptidae	ES
Nitocra hibernica	copepod	Canthocamptidae	ES
Subclass Branchiura			
Order Arguloida (fish lice)			
Argulus sp.	fish louse	Argulidae	ES
Subclass Malacostraca			
Order Isopoda (sowbugs)			
Asellus sp. [=*Caecidotea* sp.]	aquatic sowbug	Asellidae	ES
Caecidotea racovitzai racovitzai	aquatic sowbug	Asellidae	ES
Order Amphipoda (scuds)			
Crangonyx gracilis	sideswimmer	Gammaridae	ES
Gammarus fasciatus	sideswimmer	Gammaridae	ES
Gammarus pseudolimnaeus	sideswimmer	Gammaridae	ES
Hyalella azteca	sideswimmer	Talitridae	ES
Order Decapoda (crayfishes & shrimps)			
Cambarus diogones	devil crawfish	Cambaridae	ES
Orconectes rusticus	rusty crayfish	Cambaridae	ES
Palaemonetes kadiakensis	Mississippi glass shrimp	Palaemonidae	ES
CLASS INSECTA (insects)			
Order Collembola (springtails)			
entomobryid sp.	springtail	Entomobryidae	CK,ES
isotomid sp.	springtail	Isotomidae	ES
Order Diplura (diplurans)			
dipluran sp.	dipluran	Campodeidae	CK
Order Thysanura (bristletails)			
lepismatid sp.	silverfish	Lepismatidae	CK
Order Ephemeroptera (mayflies)			
Baetis sp.	bluewing olive	Baetidae	ES,TR
Caenis simulans	squaregill mayfly	Caenidae	CK
Ephemera sp.	burrowing mayfly	Ephemeridae	TR
Ephemerella sp.	spiny crawler	Ephemerellidae	CK
Ephoron sp.	pale burrowing mayfly	Polymitarcyidae	TR
Heptagenia pulla	flatheaded mayfly	Heptageniidae	CK
Heptagenia sp.	flatheaded mayfly	Heptageniidae	CK
Hexagenia limbata	burrowing mayfly	Ephemeridae	ES
Isonychia sicca	brushlegged mayfly	Oligoneuriidae	CK
Leptophlebia sp.	pronggill mayfly	Leptophlebiioidae	ES
Stenacron sp.	flatheaded mayfly or yellow may	Heptageniidae	CK,TR
Stenonema femoratum	flatheaded mayfly or pale red fox	Heptageniidae	CK

Order Odonata (damselflies & dragonflies)	Common Name	Family	Location
Aeshna sp.	blue darner or paddletail	Aeshnidae	ES
Anax junius	big green darner	Aeshnidae	ES,CK
Argia fumipennis	dancer	Coenagrionidae	TR
Argia tibialis	dancer	Coenagrionidae	CK,ES
Argia translata	dancer	Coenagrionidae	TR
Argia apicalis	dancer	Coenagrionidae	ES
Argia meosta	dancer	Coenagrionidae	ES
Argia violacea	purple damselfly or violet dancer	Coenagrionidae	ES
Calopteryx maculata [=*Agrion maculatus*]	blackwinged damselfly	Calopterygidae	CK,TR
Calopteryx sp.	bandwing damselfly	Calopterygidae	ES
Celithemis elisa	spotted skimmer/ calico pennant	Libellulidae	CK,TR
Chromagrion sp.	variegated damsel	Coenagrionidae	TR
Dromogokmphus spinosus	spinylegged clubtail	Gomphidae	TR
Dromogokmphus spoliatus	spinylegged clubtail	Gomphidae	TR
Enallagma antennatum	bluet	Coenagrionidae	CK,ES
Enallagma civile	civil bluet	Coenagrionidae	CK,ES
Enallagma exsulans	bluet	Coenagrionidae	CK
Enallagma signatum	bluet	Coenagrionidae	CK
Enallagma vespersum	bluet	Coenagrionidae	ES
Epitheca princeps	royal skimmer	Corduliidae	ES
Erythemis simplicicollis	eastern pondhawk	Libellulidae	CK,ES,TR
Hagenius brevistylus	black dragonfly	Gomphidae	TR
Hetaerina americana	American ruby spot	Calopterygidae	ES
Ischnura posita	forktail	Coenagrionidae	CK,ES
Ischnura verticalis	forktail	Coenagrionidae	CK,ES
Lestes forcipatus	marsh spreadwing	Lestidae	TR
Leucorrhinia sp.	whitefaced skimmer	Libellulidae	ES
Libellula luctuosa	widow dragonfly	Libellulidae	CK,TR
Libellula pulchella	tenspot dragonfly	Libellulidae	CK,ES
Macromia illinoiensis	river skimmer	Macromiidae	TR
Macromia taeniolata	river skimmer	Macromiidae	TR
Nehalennia irene	green damsel	Coenagrionidae	ES
Pachydiplax longipennis	blue pirate	Libellulidae	ES
Pantala flavescens	yellow skimmer	Libellulidae	TR
Pantala hymenea	globe skimmer	Libellulidae	CK,ES,TR
Perithemis tenera	eastern amber-winged skimmer	Libellulidae	CK,ES,TR
Plathemis lydia	common white-tailed skimmer	Libellulidae	CK,TR
Sympetrum rubicundulum	red skimmer	Libellulidae	TR
Sympetrum semicinctum	red skimmer	Libellulidae	TR
Tramea lacerata	raggedy skimmer	Libellulidae	TR
Tramea onusta	red saddlebags dragonfly	Libellulidae	CK
Order Blattaria (cockroaches)			
Blatta orientalis?	Oriental cockroach	Blattellidae	CK
Parcoblatta sp.?	wood cockroach	Blattellidae	CK
Periplaneta americana?	American cockroach	Blattellidae	CK
Order Mantodea (mantids)			
Tenodera aridifolia sinensis	Chinese mantid/praying mantis	Mantidae	CK,TR
Order Isoptera (termites)			
Reticulitermes flavipes	eastern subterranean termite	Rhinotermitidae	CK
Order Orthoptera (crickets & grasshoppers)			
acridid sp.	eastern lubber grasshopper	Acrididae	CK
Ceuthophilus sp.	camel or cave cricket	Gryllacrididae	CK
cyrtacanthacridin sp.	spur-throated grasshopper	Acrididae	CK
Ellipes minuta minuta	pygmy mole cricket	Tridactylidae	ES,TR
Gryllus sp.	field cricket	Gryllidae	CK
Microcentrum rhombifolium	broad-winged katydid	Tettigoniidae	CK
Neocurtilla hexadactyla	northern mole cricket	Gryllotalpidae	CK
Nomotetrix cristatus	pygmy grasshopper	Tetrigidae	TR

Order Orthoptera (cont'd)	Common Name	Family	Location
oedipidin sp.	band-winged grasshopper	Acrididae	CK
Paratettix cueullatus	pygmy grasshopper	Tetrigidae	TR
Pterophylla camellifolia	northern katydid	Tettigoniidae	CK
tetrigid sp.	pygmy grasshopper	Tetrigidae	CK
tridactylid sp.	pygmy mole cricket	Tridactylidae	ES
Order Dermaptera (earwigs)			
Euborellia annulipes?	ring-legged earwig	Labiduridae	TR
Forficula auricularia?	European earwig	Forficulidae	CK
Labia sp.?	little earwig	Labiidae	CK
Order Plecoptera (stoneflies)			
Acroneuria sp.	stonefly	Perlidae	TR
Allocapina recta	spring stonefly	Capniidae	CK
Allocapina vivapara	spring stonefly	Capniidae	CK
chloroperlid sp.	green stonefly	Chloroperlidae	CK
Isoperla duplicata	green-winged stonefly	Perlodidae	CK
nemourid sp.	broadback stonefly	Nemouridae	CK
Neoperla sp.	stonefly	Perlidae	TR
Neophasganophora sp.	great stonefly	Perlidae	TR
Paragnetina sp.	stonefly	Perlidae	CK,TR
Perlesta sp.	stonefly	Perlidae	TR
Perlinella sp.	stonefly	Perlidae	TR
taeniopterygid sp.	broadback stonefly	Taeniopterygida	CK
Order Thysanoptera (thrips)			
aeolothripid sp.	banded thrips	Aeolothripidae	CK
phlaeothripid sp.	mullin thrips	Phlaeothripidae	CK
thripid sp.	thrips	Thripidae	ES
Order Hemiptera (true bugs)			
alydid sp.	broad-headed bug	Alydidae	CK
Anasa tristis	squash bug	Coreidae	CK
Aquarius sp.	water strider	Gerridae	TR
Aradus sp.	flat bug	Aradidae	CK
Arhyssus lateralis	scentless plant bug	Rhopalidae	CK
Belostoma flumineum	giant water bug	Belostomatidae	ES
Corisella inscripta	water boatman	Corixidae	ES
Corythuca pruni	lace bug	Tingidae	CK
cydnid sp.	burrower bug	Cydnidae	CK
Euschistus icterius	stink bug	Pentatomidae	CK
Gelastocoris sp.	toad bug	Gelastocoridae	TR
Geocoris uliginosis	big-eyed bug	Lygaeidae	CK
Gerris buenoi	water strider	Gerridae	ES
Gerris canaliculatus	water strider	Gerridae	ES
Gerris comatus	water strider	Gerridae	ES
Gerris marginatus	water strider	Gerridae	ES
Gerris remigis	water strider	Gerridae	ES
Hesperocorixa lucida	water boatman	Corixidae	ES
Hesperocorixa sp.	water boatman	Corixidae	TR
Hoplistoscelus sordidus	damsel bug	Nabidae	CK
Hydrometra martini	water measurer	Hydrometridae	ES
Hydrometra sp.	water measurer	Hydrometridae	CK
Lasiomerus sp.	damsel bug	Nabidae	CK
Leptocoris trivittatus	boxelder bug	Rhopalidae	CK
Leptoglossus oppositus?	lead-footed bug	Coreidae	CK
Leptoptera dolabrata	meadow plant bug	Miridae	CK
Lygaeus kalmii	small milkweed bug	Lygaeidae	CK
Lygus lineolaris?	tarnished plant bug	Miridae	CK
Merragata sp.	velvet water bug	Hebridae	TR
Mesovelia mulsanti	water treader	Mesoveliidae	ES
Mesovelia sp.	water treader	Mesoveliidae	ES

Order Hemiptera cont'd)	Common Name	Family	Location
Metrobates hesperius	water strider	Gerridae	TR
Micracanthia sp.	shore bug	Saldidae	CK,ES
Microvelia sp.?	small water strider	Veliidae	CK,TR
Myodocha serripes	seed bug	Lygaeidae	CK
Nabis sp.	damsel bug	Nabidae	CK
Nepa sp.	oval water scorpion	Nepidae	TR
Notonecta irrorata	backswimmer	Notonectidae	ES
Notonecta raleighi lunata	backswimmer	Notonectidae	ES
Notonecta undulata	backswimmer	Notonectidae	ES
Orius insidiosus	insidious flower bug	Anthocoridae	CK
Palmacorixa buenoi	water boatman	Corixidae	ES
Palmacorixa nana	water boatman	Corixidae	ES
Palmacorixa sp.	water boatman	Corixidae	ES
Pelocoris sp.	creeping water bug	Naucoridae	ES
Peocilocapsus lineatus	four-lined leaf bug	Miridae	CK
Phymata pennsylvanica	ambush bug	Phymatidae	CK
Ranatra fusca	sticklike water scorpion	Nepidae	ES
Ranatra nigra	sticklike water scorpion	Nepidae	ES
Ranatra sp.	sticklike water scorpion	Nepidae	ES,TR
Rhagovelia sp.	small water strider	Veliidae	CK,TR
Rheumatobates sp.	water strider	Gerridae	TR
scutellerid sp.	shield-backed bug	Scutelleridae	ES
Sigara alternata	water boatman	Corixidae	ES
Sigara modesta	water boatman	Corixidae	ES
Sigara sp.	water boatman	Corixidae	CK,ES,TR
Sinea diadema	assassin bug	Reduviidae	CK
Thyanta pallido-virens	green stink bug	Pentatomidae	CK
thyreocorid sp.	negro bug	Thyreocoridae	CK
tingid sp.	lace bug	Tingidae	ES
Trepobates sp.	water strider	Gerridae	CK,ES,TR
Trichocorixa calva	water boatman	Corixidae	ES
Trichocorixa kanza	water boatman	Corixidae	ES
Trichocorixa sp.	water boatman	Corixidae	CK,ES
Zelus exsanguis	assassin bug	Reduviidae	CK
Order Homoptera (cicadas, hoppers, aphids, & scale insects)			
acanaloniid sp.	planthopper	Acanaloniidae	CK
Adelges abeitis	eastern spruce gall adelgid	Adelgidae	CK
Adelges cooleyi	Cooley spruce gall adelgid	Adelgidae	CK
Aphis pomi	green apple aphid	Aphididae	CK
Cacopsylla pyricola	pear psylla	Psyllidae	CK
Daktulosphaira vitifoliae	grape phylloxera	Phylloxeridae	CK
Draeculacephala mollipes	cicadellin leafhopper	Cicadellidae	CK
Dysaphis plantaginea	rosy apple aphid	Aphididae	CK
Empoascus fabae	potato leafhopper	Cicadellidae	CK
Eriosoma lanigerum	wooly aphid	Aphididae	CK
Graphocephala coccinea	colorful leafhopper	Cicadellidae	CK
Melaphis rhois?	sumac gall	Aphididae	CK
membracid sp.	treehopper	Membracidae	CK,ES
Myzus cerasi	black cherry aphid	Aphididae	CK
Myzus persicae	green peach aphid	Aphididae	CK
Pachypsylla celtidismamma	hackberry nipple gall	Psyllidae	CK
Penthima americana	gyponin leafhopper	Cicadellidae	CK
Periphyllus lyropictus	Norway maple aphid	Aphididae	CK
Philaenus spumarius	meadow spittlebug	Cercopidae	CK
Phylloxera caryaecaulis?	shag-bark hickory gall	Phylloxeridae	CK
Quadraspidiotus perniciosus	San Jose scale	Diaspididae	CK
Tibicen canicularis	dog day cicada	Cicadidae	CK
Tibicen linnei	dog day cicada	Cicadidae	CK
Typhlocyba pomaria	white apple leafhopper	Cicadellidae	CK

Order Neuroptera (nerve-wing insects)	**Common Name**	**Family**	**Location**
Chauliodes sp.	hellgrammite or fishfly	Corydalidae	CK,ES
Chrysopa oculata	golden eye	Chrysopidae	CK
Climacia sp.	spongillafly	Sisyridae	LE,TR
coniopterygid sp.	dustywing	Coniopterygidae	CK
Corydalus cornutus	hellgrammite	Corydalidae	CK,TR
hemerobiid sp.	brown lacewing	Hemerobiidae	CK
Sialis infumata	alderfly	Sialidae	TR
Order Coleoptera (beetles)			
Acalymma vittata?	striped cucumber beetle	Chrysomelidae	CK
Acilius sylvanus	striped diving beetle	Dytiscidae	ES
Acilius sp.	striped diving beetle	Dytiscidae	CK
Agabus sp.	diving beetle	Dytiscidae	CK,ES
Alobates pensylvanica?	darkling beetle	Tenebrionidae	CK
Altica chalybea	grape flea beetle	Chrysomelidae	CK
Anacaena limbata	water scavenger beetle	Hydrophilidae	ES
Ancyronyx sp.	riffle beetle	Elmithidae	TR
Anthicus sp.?	ant-like flower beetle	Anthicidae	CK
Anthrenus scrophulariae?	carpet beetle	Dermestidae	CK
Aphodius sp.	dung beetle	Scarabaeidae	CK
Berosus fraternus	water scavenger beetle	Hydrophilidae	ES
Berosus infuscatus	water scavenger beetle	Hydrophilidae	ES
Berosus peregrinus	water scavenger beetle	Hydrophilidae	ES
Berosus striatus	water scavenger beetle	Hydrophilidae	ES
Berosus sp.	water scavenger beetle	Hydrophilidae	CK
Bidessus sp.	diving beetle	Dytiscidae	ES
Bledius sp.	rove beetle	Staphylinidae	TR
Bolitotherus cornutus	horned fungus beetle	Tenebrionidae	CK
Brachinus sp.?	bombadier ground beetle	Carabidae	CK
brachyrhinin sp.	broad-nosed weevil	Curculionidae	CK
Brontes sp.?	flat bark beetle	Cucujidae	CK
Calathus sp.	ground beetle	Carabidae	CK
Cantharis bilineatus	soldier beetle	Cantharidae	CK
Carpophilus sp.	carpophilin sap beetle	Nitidulidae	CK
cerambycid sp.	locust borer beetle	Cerambycidae	CK
Chauliognathus marginata	soldier beetle	Cantharidae	CK
Chauliognathus pennsylvanicus?	soldier beetle	Cantharidae	CK
Chilocorus stigma	twice-stabbed ladybug	Coccinellidae	CK
Chrysobothris femorata	flat-headed apple tree borer	Buprestidae	CK
Chrysochus auratus	dogbane beetle	Chrysomelidae	CK
Cicindela sp.	tiger beetle	Carabidae	CK
clerid sp.?	checkered beetle	Cleridae	CK
Colaulon sp.	click beetle	Elateridae	CK
Coleomegilla sp.	ladybird beetle	Coccinellidae	CK
Conotrachelus nenuphar	plum curculio	Curculionidae	CK
Copelatus glyphius	diving beetle	Dytiscidae	ES
Copelatus sp.	diving beetle	Dytiscidae	ES
Coptotomus lenticus	diving beetle	Dytiscidae	ES
Creophilus maxillosus	rove beetle	Staphylinidae	CK
Curculio sp.	chestnut weevil	Curculionidae	CK
Curculio sp.	nut weevil	Curculionidae	CK
curculionid sp.	weevil	Curculionidae	CK
Cymbiodyta sp.	water scavenger beetle	Hydrophilidae	ES
Cyphon sp.	marsh beetle	Scirtidae	ES
Cyrtophorus verrucosus	long-horned beetle	Cerambycidae	CK
Dermestes lardarius?	larder beetle	Dermestidae	CK
Derodontus sp.	tooth-necked fungus beetle	Derodontidae	CK
Diabrotica undecimpunctata howardi	spotted cucumber beetle	Chrysomelidae	CK
Dineutus assimilis	whirligig beetle	Gyrinidae	ES
Dineutus sp.	whirligig beetle	Gyrinidae	CK,ES
Disonycha sp.	leaf beetle	Chrysomelidae	CK

Order Coleoptera (cont'd)	Common Name	Family	Location
Donacia sp.	leaf beetle	Chrysomelidae	ES
Dubiraphia bivittata	riffle beetle	Elmithidae	ES
Dubiraphia sp.	riffle beetle	Elmithidae	ES,TR
Dytiscus fasciventris	diving beetle	Dytiscidae	ES
Elaphidionoides sp. [=*Elaphidion*]	longhorn twig pruner beetle	Cerambycidae	CK
Elaprus ruscarius	marsh or bog beetle	Carabidae	CK
Ellychnia sp.	firefly or lightningbug	Lampyridae	CK
endomychid sp.	handsome fungus beetle	Endomychidae	CK
Enochrus hamiltoni	water scavenger beetle	Hydrophilidae	ES
Enochrus ochraceus	water scavenger beetle	Hydrophilidae	CK,ES
Enochrus perplexus	water scavenger beetle	Hydrophilidae	ES
Enochrus pygmaeus nebulosus	water scavenger beetle	Hydrophilidae	ES
Enochrus sayi	water scavenger beetle	Hydrophilidae	ES
Epicauta sp.	blister beetle	Meloidae	CK
Epilachna varivestis	Mexican bean beetle	Coccinellidae	CK
erotylid sp.?	pleasing fungus beetle	Erotylidae	CK
Euphoria inda?	bumble flower beetle	Scarabaeidae	CK
Glischrochilus fasciatus	cryptarchin sap beetle	Nitidulidae	CK
Haliplus borealis	crawling water beetle	Haliplidae	ES
Haliplus immaculicollis	crawling water beetle	Haliplidae	ES
Haliplus triopsis	crawling water beetle	Haliplidae	ES,TR
Harmonia axyridis	Asiatic lady beetle	Coccinellidae	CK
Harpalus compar	ground beetle	Carabidae	CK
Harpalus herbivagus	ground beetle	Carabidae	CK
Helichus sp.	long-toed water beetle	Dryopidae	CK,ES
Helophorus lineatus	water scavenger beetle	Hydrophilidae	ES
Helophorus orientalis	water scavenger beetle	Hydrophilidae	ES
Helophorus marginicollis	water scavenger beetle	Hydrophilidae	ES
Helophorus sp.	water scavenger beetle	Hydrophilidae	ES
Heterocerus sp.	variegated mud-loving beetle	Heteroceridae	ES,TR
Heterosternuta wickhami	diving beetle	Dytiscidae	ES
Hippodamia convergens?	covergent ladybird beetle	Coccinellidae	CK
Hister foedatus	hister beetle	Histeridae	CK
Homaeotarsus sp.?	rove beetle	Staphylinidae	CK
Hoplia sp.	grapevine beetle	Scarabaeidae	CK
Hydrobius fuscipes	water scavenger beetle	Hydrophilidae	ES
Hydrocanthus iricolor	burrowing water beetle	Noteridae	ES
Hydrochara leechi	water scavenger beetle	Hydrophilidae	ES
Hydrochara obtusata	water scavenger beetle	Hydrophilidae	TR
Hydrochara sp.	water scavenger beetle	Hydrophilidae	ES
Hydrophilus sp.	water scavenger beetle	Hydrophilidae	TR
Hydroporus niger	diving beetle	Dytiscidae	ES
Hydroporus sp.	diving beetle	Dytiscidae	CK,ES
Hydrovatus sp.	diving beetle	Dytiscidae	CK,ES
Hygrotus dissimilis	diving beetle	Dytiscidae	ES
Hygrotus impressopunctatus	diving beetle	Dytiscidae	ES
Hygrotus sayi	diving beetle	Dytiscidae	ES
Hyperodes sp.	weevil	Curculionidae	TR
Ilybius sp.	diving beetle	Dytiscidae	CK
Laccobius sp.	water scavenger beetle	Hydrophilidae	ES
Laccophilus maculosus maculosus	diving beetle	Dytiscidae	ES
Laccophilus sp.	diving beetle	Dytiscidae	CK
Leptinotarsa decemlineata	Colorado potato beetle	Chrysomelidae	CK
leptodirin sp.	small carrion beetle	Leiodidae	CK
Lucidota atra	firefly or lightningbug	Lampyridae	CK
Lucidota punctata	firefly or lightningbug	Lampyridae	CK
lyctin sp.?	powder-post beetle	Bostrichidae	CK
Lytta aenea?	blister beetle	Meloidae	CK
Macrodactylus subspinosus	rose chafer	Scarabaeidae	CK
Megacyllene robiniae	locust borer	Cerambycidae	CK

Order Coleoptera (cont'd)	Common Name	Family	Location
Melanotus sp.	click beetle	Elateridae	CK
melolonthin sp.	May beetle	Scarabaeidae	CK
melyrid sp.	soft-winged flower beetle	Melyridae	CK
Microcylloepus sp.	riffle beetle	Elmithidae	ES
Neoporus sp.	diving beetle	Dytiscidae	ES
noterid sp.	burrowing water beetle	Noteridae	ES
Oberea bimaculata	raspberry cane borer	Cerambycidae	CK
Odontota dorsalis?	locust leaf beetle	Chrysomelidae	CK
Paederus littorarius	rove beetle	Staphylinidae	CK
Paracymus subcupreus	water scavenger beetle	Hydrophilidae	ES
Parandra brunnea	pole borer	Cerambycidae	CK
Pelidnota punctata	grapevine beetle	Scarabaeidae	CK
Peltodytes duodecimpunctatus	crawling water beetle	Haliplidae	ES
Peltodytes edentulus	crawling water beetle	Haliplidae	ES
Peltodytes lengi	crawling water beetle	Haliplidae	ES
Peltodytes muticus	crawling water beetle	Haliplidae	ES
Peltodytes sexmaculatus	crawling water beetle	Haliplidae	ES
Peltodytes sp.	crawling water beetle	Haliplidae	ES
phalacrid sp.?	shining mold beetle	Phalacridae	CK
Photinus pyralis	firefly or lightningbug	Lampyridae	CK
Photuris pennsylvanica	firefly or lightningbug	Lampyridae	CK
Phyllophaga sp.	June beetle or junebug	Scarabaeidae	CK
Platynus placidus	ground beetle	Carabidae	CK
Podabrus flavicollis?	soldier beetle	Cantharidae	CK
Podabrus modestus?	soldier beetle	Cantharidae	CK
Popilia japonica	Japanese beetle	Scarabaeidae	CK
Psephenus herricki	water-penny beetle	Psephenidae	CK,TR
Pseudolucanus sp.	pinching beetle	Lucanidae	CK
Quedius sp?	large rove beetle	Staphylinidae	CK
Rhantus sp.	diving beetle	Dytiscidae	CK
salpingid sp.	narrow-waisted bark beetle	Salpingidae	ES
Saprinus sp.	hister beetle	Histeridae	CK
Scarites subterraneus?	ground beetle	Carabidae	CK
Scolytus rugulosus	shot-hole borer	Curculionidae	CK
Silpha americana	carrion beetle	Silphidae	CK
Sphenophorus sp.	billbug weevil	Curculionidae	CK
Staphylinus sp.	rove beetle	Staphylinidae	CK
Stelidiota octomaculata	tiny sap beetle	Nitidulidae	CK
Stenelmis crenata	riffle beetle	Elmithidae	ES
Stenelmis sp.	riffle beetle	Elmithidae	CK,TR
Stenolophus sp.?	ground beetle	Carabidae	CK
Stenus sp.	rove beetle	Staphylinidae	CK,TR
Stethorus punctum	black lady beetle	Coccinellidae	CK
Telephanus velox?	flat bark beetle	Cucujidae	CK
Tetraopes sp.	milkweed beetle	Cerambycidae	CK
thylactin sp.	snout beetle	Curculionidae	CK
Tropisternus lateralis nimbatus	narrow water scavenger beetle	Hydrophilidae	ES,TR
Tropisternus natator	narrow water scavenger beetle	Hydrophilidae	ES
Tropisternus sp.	narrow water scavenger beetle	Hydrophilidae	CK,ES,TR
Xenochalepus dorsalis	locust leafminer	Chrysomelidae	CK
Order Mecoptera (scorpionflies)			
Panorpa helena?	common scorpionfly	Panorpidae	CK
Order Siphonaptera (fleas)			
Ctenocephalides canis	dog flea	Pulicidae	CK
Ctenocephalides felis	cat flea	Pulicidae	CK
Order Diptera (true flies)			
Ablabesmyia parajanta	midge	Chironomidae	ES
Aedes communis?	mosquito	Culicidae	CK

Order Diptera (cont'd)	Common Name	Family	Location
Aedes infirmatus	mosquito	Culicidae	ES
Aedes vexans	mosquito	Culicidae	ES
anthomyzid sp.	anthomyzid fly	Anthomyzidae	CK
Anthrax sp.	bee fly	Bombyliidae	CK
Aphidoletes aphidimyza	orange maggot or gall gnat	Cecidomyiidae	CK
asilid sp.	robber fly	Asilidae	CK
asteiid sp.	asteiid fly	Asteiidae	CK
Atherix varigata	snipe fly	Athericidae	TR
Baccha sp.?	flower fly	Syrphidae	CK
Bibio sp.?	march fly	Bibionidae	CK
blepharocerid sp.	net-winged midge	Blepharoceridae	ES
Brachypremna sp.	crane fly	Tipulidae	CK,TR
Chaoborus flavicans	phantom midge	Chaoboridae	ES
Chaoborus punctipennis	phantom midge	Chaoboridae	ES
Chironomus anthracinus	midge	Chironomidae	ES
Chironomus cristatus	midge	Chironomidae	ES
Chironomus decorus	midge	Chironomidae	ES
Chironomus plumosus	midge	Chironomidae	ES
Chironomus riparus	midge	Chironomidae	ES
Chironomus staegeri	midge	Chironomidae	ES
Chironomus tentans	midge	Chironomidae	ES
chloropid sp.	frit fly	Chloropidae	CK
Chrysops sp.	deer fly	Tabanidae	CK,TR
Cladopelma sp.	midge	Chironomidae	ES
Cladotanytarsus sp.	midge	Chironomidae	ES
Coelotanypus concinnus	midge	Chironomidae	ES
Cricotopus sylvestris	midge	Chironomidae	ES
Cricotopus tremulus	midge	Chironomidae	ES
Cricotopus trifascia	midge	Chironomidae	ES
Cryptochironomus sp.	midge	Chironomidae	ES
Culex pipiens	mosquito	Culicidae	CK
Dicrotendipes nervous	midge	Chironomidae	ES
Dicrotendipes sp.	midge	Chironomidae	ES
Didea sp.	flower fly	Syrphidae	CK
dolichopodid sp.	long-legged fly	Dolichopodidae	CK
Drosophila melanogaster	pomace fly	Drosophilidae	CK
Endochironomus nigrans	midge	Chironomidae	ES
ephydrid sp.	shore fly	Ephydridae	CK,ES
Eristalis tenax?	hover fly	Syrphidae	CK
Eurosta solidaginis	round ball goldenrod gall	Tephritidae	CK
Glyptotendipes loberiferus	midge	Chironomidae	ES
Glyptotendipes sp.	midge	Chironomidae	ES
Hedriodiscus sp.	soldier fly	Stratiomyidae	ES
heleomyzid sp.	heleomyzid fly	Heleomyzidae	CK
Helicobia sp.	flesh fly	Sarcophagidae	CK
Hexatoma sp.	crane fly	Tipulidae	TR
Hydrobaenus sp.	midge	Chironomidae	ES
Labrundinia pilosilla	midge	Chironomidae	ES
lauxaniid sp.	lauxaniid fly	Lauxaniidae	CK
Limnochironomus tenuicadatus	midge	Chironomidae	ES
Limnophyes sp.	midge	Chironomidae	ES
Lipiniella sp.	midge	Chironomidae	ES
lonchopterid sp.	spear-winged fly	Lonchpoteridae	ES
Lucilia illustris?	blow fly	Calliphoridae	CK
Merycomia sp.	horse fly	Tabanidae	TR
Microchironomus sp.	midge	Chironomidae	ES
Micropsectra polita	midge	Chironomidae	ES
Microtendipes caelum	midge	Chironomidae	ES
Musca sp.	house fly	Muscidae	CK
mycetophilid sp.	fungus gnat	Mycetophilidae	CK,ES

Order Diptera (cont'd)	Common Name	Family	Location
Odontomyia sp.	soldier fly	Stratiomyidae	ES
Orthocladius obumbratus	midge	Chironomidae	ES
Orthocladius sp.	midge	Chironomidae	ES
Parachironomus sp.	midge	Chironomidae	ES
Paradelphomyia sp.	crane fly	Tipulidae	TR
Paralauterborniella sp.	midge	Chironomidae	ES
Paratanytarsus sp.	midge	Chironomidae	ES
Paratendipes sp.	midge	Chironomidae	ES
Pedicia sp.	crane fly	Tipulidae	TR
Pentaneura sp.	midge	Chironomidae	ES
phorid sp.	humpbacked fly	Phoridae	CK,ES
Pollenia sp.?	cluster blow fly	Calliphoridae	CK
Polypedilum halterale	midge	Chironomidae	ES
Polypedilum sp.	midge	Chironomidae	ES
Potthastia longimanus	midge	Chironomidae	ES
Probezzia sp.	biting midge	Ceratopogonidae	ES
Procladius sp.	midge	Chironomidae	ES
Procladius sublettei	midge	Chironomidae	ES
Protoplasa sp.?	primitive crane fly	Tanyderidae	CK
ptychopterid sp.	phantom crane fly	Ptychopteridae	CK
Rhagio sp.	snipe fly	Rhagionidae	CK
Rhagoletis pomonella	apple maggot	Tephritidae	CK
Rheotanytatsus exiguus	midge	Chironomidae	ES
Rhopalomyia solidaginis	leafy goldenrod gall	Cecidomyiidae	CK
sciarid sp.	dark-winged fungus gnat	Sciaridae	CK
sciomyzid sp.	marsh fly	Sciomyzidae	ES
Simulium sp.	black fly	Simuliidae	CK,ES
Spoggosia sp.?	tachina fly	Tachinidae	CK
Stictochironomus sp.	midge	Chironomidae	ES
Stratiomys sp.	soldier fly	Stratiomyidae	CK
Sympotthastia sp.	midge	Chironomidae	ES
Syrphus sp**.**	hover fly	Syrphidae	CK
Tabanus sp.	horse fly	Tabanidae	CK,TR
Tanypus sp.	midge	Chironomidae	ES,TR
Tanytarsus glabrescens	midge	Chironomidae	ES
therevid sp.	stiletto fly	Therevidae	CK
Thienemannimyia sp.	midge	Chironomidae	ES
Tipula sp.	crane fly	Tipulidae	CK,ES,TR
Tribelos sp.	midge	Chironomidae	ES
Trichocera sp.?	winter crane fly	Trichoceridae	CK
Order Trichoptera (caddisflies)			
Agraylea sp.	caddisfly	Hydroptilidae	CK,ES
Ceraclea cancellatus	caddisfly	Leptoceridae	CK
Ceraclea resurgens	caddisfly	Leptoceridae	CK
Ceraclea tarsi-punctata	caddisfly	Leptoceridae	CK,ES
Ceraclea transversus	caddisfly	Leptoceridae	ES
Ceraclea sp.	caddisfly	Leptoceridae	CK
Ceratopsyche bronta	caddisfly	Hydropsychidae	ES
Ceratopsyche slossonae	caddisfly	Hydropsychidae	ES
Ceratopsyche sp.	caddisfly	Hydropsychidae	ES,TR
Cernotina ohio	caddisfly	Polycentropodidae	ES
Cheumatopsyche burksi	caddisfly	Hydropsychidae	ES
Cheumatopsyche campyla	caddisfly	Hydropsychidae	CK
Cheumatopsyche minuscula	caddisfly	Hydropsychidae	ES
Cheumatopsyche pasella	caddisfly	Hydropsychidae	ES
Cheumatopsyche sordida	caddisfly	Hydropsychidae	CK,ES
Cheumatopsyche sp.	caddisfly	Hydropsychidae	ES,TR
Chimarra obscura	caddisfly	Philopotamidae	CK,ES
Cyrnellus fraternus	caddisfly	Polycentropodidae	CK,ES
Cyrnellus marginalis	caddisfly	Polycentropodidae	ES

Order Trichoptera (cont'd)	Common Name	Family	Location
Helicopsyche sp.	caddisfly	Helicopsychidae	TR
Hydropsyche betteni	caddisfly	Hydropsychidae	CK,ES
Hydropsyche recurvata	caddisfly	Hydropsychidae	CK,ES
Hydropsyche sp.	caddisfly	Hydropsychidae	CK,ES,TR
Hydropsyche walkeri	caddisfly	Hydropsychidae	CK
Hydroptila ajax	caddisfly	Hydroptilidae	CK,ES
Hydroptila angusta	caddisfly	Hydroptilidae	CK
Hydroptila armata	caddisfly	Hydroptilidae	ES
Hydroptila consimilis	caddisfly	Hydroptilidae	ES
Hydroptila grandiosa	caddisfly	Hydroptilidae	CK
Hydroptila perdita	caddisfly	Hydroptilidae	CK,ES
Hydroptila spatulata	caddisfly	Hydroptilidae	CK
Hydroptila waubesiana	caddisfly	Hydroptilidae	CK,ES
Leptocerus americanus	caddisfly	Leptoceridae	CK
Limnephilus submonilifer	caddisfly	Limnephilidae	CK
Nectopsyche sp.	caddisfly	Leptoceridae	CK,ES
Neophylax sp.	caddisfly	Limnephilidae	CK
Neureclipsis crepuscularis	caddisfly	Polycentropodidae	ES
Nyctiophylax moestus	caddisfly	Polycentropodidae	CK,ES
Ochrotrichia tarsalis	caddisfly	Hydroptilidae	CK,ES
Oecetis avara	caddisfly	Leptoceridae	ES
Oecetis cinerascens	caddisfly	Leptoceridae	CK,ES
Oecetis inconspicua	caddisfly	Leptoceridae	CK,ES
Oecetis persimilus	caddisfly	Leptoceridae	CK
Orthotrichia americana	caddisfly	Hydroptilidae	CK,ES
Oxeythira pallida	caddisfly	Hydroptilidae	ES
Philarctus sp.?	caddisfly	Limnephilidae	ES
Phryganea cinerea	caddisfly	Phryganeidae	ES
Polycentropus interruptus	caddisfly	Polycentropodidae	ES
Polycentropus aureolus	caddisfly	Polycentropodidae	CK
Polycentropus cinereus	caddisfly	Polycentropodidae	CK
Polycentropus crassicornis	caddisfly	Polycentropodidae	ES
Potamyia sp.	caddisfly	Hydropsychidae	CK,TR
Pycnopsyche sp.	caddisfly	Limnephilidae	TR
Rhyacophila ledra	caddisfly	Rhyacophilidae	CK
Rhyacophila vibox	caddisfly	Rhyacophilidae	CK
Triaenodes frontalis	caddisfly	Leptoceridae	ES
Order Lepidoptera (butterflies & moths)			
Alypia sp.	forester moth	Agaristidae	CK
Antheraea polyphemus	polyphemus moth	Saturniidae	CK
Archips argyrospila	fruittree leaf-roller	Tortricidae	CK
Argyrotaenia velutinana	red-banded leaf-roller	Tortricidae	CK
Asterocampa celtis	hackberry buttertfly	Nymphalidae	CK
Asterocampa clyton	tawny emperor	Nymphalidae	CK
Autographa sp.	looper moth	Noctuidae	CK
Automeris io	io moth	Saturniidae	CK
Battus philenor	pipevine swallowtail	Papilionidae	CK
Boloria bellona bellona	meadow fritillary	Nymphalidae	CK
Catocala sp.	underwing moth	Noctuidae	CK
Celastrina ladon ladon	spring azure	Lycaenidae	CK
Cercyonis pegala	common wood nymph	Satyridae	CK
Choristoneura rosaceana	oblique-banded leaf-roller	Tortricidae	CK
Colias eurytheme	orange sulfur	Pieridae	CK
Colias philodice	common sulfur	Pieridae	CK
Crambus sp.	close-wings or grass moth	Pyralidae	CK
Ctenucha virginica	ctenuchid Virginia moth	Ctenuchidae	CK
Cydia pomonella	codling moth	Tortricidae	CK
Danaus plexippus	monarch butterfly	Danaidae	CK
Enodia anthedon	northern pearly eye	Nymphalidae	CK
Epargyreus clarus	silver-spotted skipper	Hesperiidae	CK

Order Lepidoptera (cont'd)	Common Name	Family	Location
Erynnis baptisiae	wild indigo duskywing skipper	Hesperiidae	CK
Estigmene sp.?	white moth	Arctiidae	CK
Euchoeca albovitatta	white-striped black moth	Geometridae	CK
Euzophera semifuneralis	American plum borer	Pyralidae	CK
Everes comyntas	eastern tailed blue	Lycaenidae	CK
Gnorimoschema gallaesolidaginis	golden rod gall	Gelechiidae	CK
Grapholitha molesta	Oriental fruit moth	Tortricidae	CK
Haemotopis grataria	chickweed geometer moth	Geometridae	CK
Heliothis zea	corn earworm	Noctuidae	CK
Hemerocampa leucostigma	white-marked tussock moth	Lymantriidae	CK
Hyphantria cunea	fall webworm	Arctiidae	CK
Isia isabella	banded woolybear	Arctiidae	CK
Junonia coenia	buckeye	Nymphalidae	CK
Libytheana bachmanii	snout butterfly	Libytheidae	CK
Limenitis archippus	viceroy	Nymphalidae	CK
Limenitis arthemis astyanax	red-spotted purple	Nymphalidae	CK
Lycaena phlaeas	American copper	Lycaenidae	CK
Malacosoma americanum	eastern tent caterpillar	Lasiocampidae	CK
Manduca quinquemaculata	tomato hornworm	Sphingidae	CK
Megisto cymela	little wood satyr	Satyridae	CK
notodontid sp.	prominent moth	Notodontidae	CK
Nymphalis antiopa	mourning cloak	Nymphalidae	CK
Nymphalis milberti	Milbert's tortoise shell	Nymphalidae	CK
Ostrinia nubilalis	European corn borer	Pyralidae	CK
Papaipema nebris	stalk borer	Noctuidae	CK
Papilio cresphontes	giant swallowtail	Papilionidae	CK
Papilio glaucus	tiger swallowtail	Papilionidae	CK
Papilio polyxenes asterius	black swallowtail	Papilionidae	CK
Papilio troilus	spicebush swallowtail	Papilionidae	CK
Paralobesia viteana	grape berry moth	Tortricidae	CK
Pennisetia marginata	raspberry crown borer	Sesiidae	CK
Pholisora catullus	common sootywing skipper	Hesperiidae	CK
Phyciodes tharos	pearl crescent	Nymphalidae	CK
Phyllonorycter blancardella	spotted tentiform leafminer	Gracillariidae	CK
Pieris rapae	cabbage white	Pieridae	CK
Platy nota flavedana	variegated leaf-roller	Tortricidae	CK
Platynota idaeusalis	tufted apple bud-moth	Tortricidae	CK
Platysamia cecropia	cecropia moth	Saturniidae	CK
Plodia interpuncatata	Indian meal moth	Pyralidae	CK
Poanes zabulon	southern golden skipper	Hesperiidae	CK
Podosesia syringae syringae	lilac borer	Sesiidae	CK
Polites coras [=*Polites peckius*]	yellowpatch or Peck's skipper	Hesperiidae	CK
Polygonia interrogationis	question-mark	Nymphalidae	CK
Protoparce sexta?	sphinx moth	Sphingidae	CK
Speyeria sp.	fritillary or silverspot	Nymphalidae	CK
sphingid sp.	clear-wing sphinx moth	Sphingidae	CK
Spilonota ocellana	eye-spotted bud-moth	Tortricidae	CK
Synanthedon exitiosa	peach tree borer	Sesiidae	CK
Synanthedon pictipes	lesser peach tree borer	Sesiidae	CK
Synanthedon scitula	dogwood borer	Sesiidae	CK
Synchlora aerata	green geometrid moth	Geometridae	CK
tineid sp.	clothes moth	Tineidae	CK
Vanessa atalanta rubria	red admiral	Nymphalidae	CK
Vanessa cardui	painted lady	Nymphalidae	CK
Vanessa virginiensis	American painted lady	Nymphalidae	CK
yponomeutoid sp.	ermine moth	Yponomeutoidea	ES
Order Hymenoptera (ants, bees, sawflies, & wasps)			
Acanthomyops sp.	foundation ant	Formicidae	CK
Agapostemon sp.	halictid bee	Halictidae	CK

Order Hymenoptera (cont'd)	Common Name	Family	Location
Amphibolips sp.?	oak apple gall	Cynipidae	CK
andrenid sp.	andrenid bee	Andrenidae	CK
anthophorid sp.	digger bee	Anthophoridae	CK
Apis mellifera	honey bee	Apidae	CK
Bombus sp.	large bumblebee	Apidae	CK
braconid sp.	braconid wasp	Braconidae	CK
Camponotus sp.	carpenter ant	Formicidae	CK
Chalybion sp.?	thread-waisted wasp	Sphecidae	CK
chrysidid sp.	cuckoo wasp	Chrysididae	CK
colletid sp.	colletid bee	Colletidae	CK
Crematogaster sp.	small black ant	Formicidae	CK
Diastrophus cuscutaeformis	blackberry gall	Cynipidae	CK
Diastrophus nebulosis	blackberry gall-maker	Cynipidae	CK
Eumenes sp.?	potter wasp	Eumenidae	CK
eurytomid sp.	chalid seed wasp	Eurytomidae	CK
evaniid sp.	ensign wasp	Evaniidae	ES
Formica sp.	mound builder ant	Formicidae	CK
halictid sp.	halictid bee	Halictidae	CK
ichneumonid sp.	ichneumon wasp	Ichneumonidae	CK,ES
Lasius sp.	winged ant	Formicidae	CK
Leptothorax sp.	ant	Formicidae	CK
megachilid sp.	leafcutting bee	Megachilidae	CK
Megarhyssa sp.?	ichneumon wasp	Ichneumonidae	CK
Monobia sp.?	potter wasp	Eumenidae	CK
Monomorium pharaonis?	Pharaoh ant	Formicidae	CK
Myrmica sp.	ant	Formicidae	CK
nomadin sp.?	cuckoo bee	Anthophoridae	CK
polistin sp.	paper wasp	Vespidae	CK
Ponera sp.	ant	Formicidae	CK
Prenolepis sp.	ant	Formicidae	CK
proctotrupid sp.	parasitic wasp	Proctotrupidae	CK
Sphecius speciosus	cicada killer wasp	Sphecidae	CK
tenthredinid sp.	sawfly	Tenthredinidae	CK
Tetramorium caespitum	pavement ant	Formicidae	CK
tiphiid sp.	tiphiid wasp	Tiphiidae	CK,ES
torymid sp.	parasitic wasp	Torymidae	CK
Tremex sp.?	horntail sawfly	Siricidae	CK
Vespa crabro germana	giant hornet	Vespidae	CK
Vespula germanica	picnic wasp	Vespidae	CK
Vespula maculata	bald-faced hornet	Vespidae	CK
Vespula maculifrons?	yellowjacket wasp	Vespidae	CK
Xylocopa virginica?	large carpenter bee	Anthophoridae	CK
PHYLUM TARDIGRADA (water bears)			
Order Eutardigrada			
macrobiotid sp.	water bear	Macrobiotidae	ES
PHYLUM BRYOZOA [=ECTOPROCTA] (bryozoans)			
CLASS PHYLACTOLAEMATA			
Order Plumatellida			
Lophopodella carteri	sac bryozoan	Lophopodidae	ES
Pectinatella magnifica	slimy bryozoan	Lophopodidae	ES
Plumatella casmiana	bryozoan	Plumatellidae	ES
Plumatella repens	spreading bryozoan	Plumatellidae	ES

Location Codes:

CK – Old Woman Creek watershed upstream of the estuary
ES – Old Woman Creek Estuary (including watershed within boundaries of NERR)
LE – Lake Erie, principally nearshore waters of Erie County and western Lorain County, Ohio
TR – Tributary watersheds to Lake Erie other than Old Woman Creek, principally of eastern Erie County and western Lorain County, Ohio

APPENDIX D. FISH FAUNA OF OLD WOMAN CREEK ESTUARY AND WATERSHED, AND ADJACENT TRIBUTARIES AND WATERS OF LAKE ERIE

LAMPREYS (Petromyzontidae)	Common Name	Location
Ichthyomyzon unicuspis	silver lamprey	LE,TR
Petromyzon marinus	sea lamprey	LE
STURGEONS (Acipenseridae)		
Acipenser fulvescens	lake sturgeon	LE
GARS (Lepisosteidae)		
Lepisosteus osseus	longnose gar	ES,LE,TR
BOWFINS (Ammidae)		
Amia calva	bowfin	ES,LE,TR
HERRINGS (Clupeidae)		
Alosa pseudoharengus	alewife	ES,LE,TR
Dorosoma cepedianum	gizzard shad	ES,LE,TR
WHITEFISHES (Coregoninae)		
Coregonus clupeaformis	lake whitefish	LE
MOONEYES (Hiodontidae)		
Hiodon tergisus	mooneye	LE
SALMONS AND TROUTS (Salmoninae)		
Oncorhynchus kisutch	coho salmon	ES,LE,TR
Oncorhynchus tshawytscha	chinook salmon	LE,TR
Oncorhynchus maykiss	rainbow or steelhead trout	CK,ES,LE,TR
Salvelinus fontinalis	brook trout	TR
Salmo trutta	brown trout	TR
SMELTS (Osmeridae)		
Osmerus mordax	rainbow smelt	LE
MUDMINNOWS (Umbridae)		
Umbra limi	central mudminnow	ES,TR
PIKES (Esocidae)		
Esox americanus	grass pickerel	TR
Esox lucius	northern pike	CK,ES,LE,TR
Esox masquinongy	muskellunge	LE
Esox niger	chain pickerel	TR
CARPS AND MINNOWS (Cyprinidae)		
Campostoma anomalum	stoneroller minnow	CK,ES,TR
Carassius auratus	goldfish	ES,LE,TR
Clinostomus elongatus	redside dace	LE,TR
Cyprinella spilopterua	spotfin shiner	ES,LE,TR
Cyprinus carpio	common carp	ES,LE,TR
Hybopsis amblops	bigeye chub	TR
Hybopsis storeriana	silver chub	ES,LE,TR
Luxilus chrysocephalus	striped shiner	LE,TR
Luxilus cornutus	common shiner	CK,ES,TR
Lythrurus umbratilis	redfin shiner	TR
Nocomis biguttatus	hornyhead chub	TR
Nocomis micropogon	river chub	TR
Notemigonus crysoleucas	golden shiner	ES,LE,TR
Notropis atherinoides	emerald shiner	CK,ES,LE,TR
Notropis buccata	silverjaw minnow	LE,TR
Notropis buchanani	ghost shiner	LE,TR
Notropis dorsalis	bigmouth shiner	TR

	Common Name	Location
CARPS AND MINNOWS (cont'd)		
Notropis emiliae	pugnose minnow	TR
Notropus heterolepis	blacknose shiner	LE
Notropis hudsonius	spottail shiner	ES,LE,TR
Notropis photogenis	silver shiner	TR
Notropis rubellus	rosyface shiner	ES,TR
Notropis stramineus	sand shiner	ES,LE,TR
Notropis volucellus	mimic shiner	LE,TR
Phoxinus erythrogaster	southern redbelly dace	TR
Pimephales notatus	bluntnose minnow	CK,ES,LE,TR
Pimephales promelas	northern fathead minnow	ES,TR
Rhinichthys atratulus	blacknose dace	CK,TR
Rhinichthys cataractae	longnose dace	LE
Semotilus atromaculatus	northern creek chub	ES,CK,TR
SUCKERS (Catostomidae)		
Carpiodes cyprinus	quillback carpsucker	ES,LE,TR
Catostomus commersoni	white sucker	CK,ES,LE,TR
Hypentelium nigricans	northern hog sucker	LE,TR
Ictiobus bubalus	smallmouth buffalo	ES,LE,TR
Ictiobus cyprinellus	bigmouth buffalo	LE,TR
Minytrema melanops	spotted sucker	ES,LE,TR
Moxostoma anisurum	silver redhorse	LE,TR
Moxostoma duquesnei	black redhorse	ES,LE,TR
Moxostoma erythrurum	golden redhorse	ES,LE,TR
Moxostoma macrolepidotum	shorthead redhorse	ES,LE,TR
BULLHEAD CATFISHES (Ictaluridae)		
Ameiurus melas	black bullhead	ES,TR
Ameiurus natalis	yellow bullhead	ES,LE,TR
Ameiurus nebulosus	brown bullhead	ES,LE,TR
Ictalurus punctatus	channel catfish	ES,LE,TR
Noturus flavus	stonecat madtom	ES,LE,TR
Noturus gyrinus	tadpole madtom	ES,TR
Noturus miurus	brindled madtom	LE,TR
Pylodictis olivaris	flathead catfish	LE,TR
TROUT-PERCHES (Percopsidae)		
Percopsis omincomaycus	trout-perch	LE,TR
CODFISHES (Gadidae)		
Lota lota	burbot	LE
KILLIFISHES (Cyprinodontidae)		
Fundulus diaphanus menona	western banded killifish	TR
SILVERSIDES (Poecillidae)		
Labidesthes sicculus	brook silverside	ES,LE,TR
TEMPERATE BASSES (Percichthyidae)		
Morone americana	white perch	ES,LE,TR
Morone chrysops	white bass	ES,LE,TR
SUNFISHES (Centrarchidae)		
Ambloplites rupestris	rock bass	LE,TR
Lepomis cyanellus	green sunfish	CK,ES,LE,TR
Lepomis gibbosus	pumpkinseed	CK,ES,LE,TR
Lepomis humilis	orangespotted sunfish	ES,TR
Lepomis macrochirus	bluegill sunfish	ES,LE,TR
Lepomis megalotis peltastes	northern longear sunfish	TR
Micropterus dolomieui	smallmouth bass	ES,LE,TR
Micropterus salmoides	largemouth bass	CK,ES,LE,TR
Pomoxis annularis	white crappie	ES,LE,TR
Pomoxis nigromaculatus	black crappie	ES,LE,TR

PERCHES (Percidae)	Common Name	Location
Ammocrypta pellucida	eastern sand darter	LE,TR
Etheostoma blennioides	greenside darter	TR
Etheostoma caeruleum	rainbow darter	CK,LE,TR
Etheostoma exile	Iowa darter	LE,TR
Etheostoma flabellare	fantail darter	LE,TR
Etheostoma nigrum	johnny darter	ES,TR
Perca flavescens	yellow perch	ES,LE,TR
Percina caprodes	logperch darter	ES,LE,TR
Percina copelandi	channel darter	LE,TR
Percina maculata	blackside darter	TR
Stizostedion canadense	sauger	LE
Sander vitreus vitreus	walleye	ES,LE,TR
DRUMS (Sclaenidae)		
Aplodinotus grunniens	freshwater drum	ES,LE,TR
SCULPINS (Cottidae)		
Cottus bairdi	mottled sculpin	LE,TR

Location Codes:

CK – Old Woman Creek upstream of the estuary
ES – Old Woman Creek estuary
LE – Lake Erie, principally nearshore waters of eastern Erie County and western Lorain County, Ohio
TR – Tributary waters to Lake Erie other than Old Woman Creek, principally of eastern Erie County and western Lorain County, Ohio

APPENDIX E. AVIFAUNA OF OLD WOMAN CREEK ESTUARY, WATERSHED, AND ADJACENT TRIBUTARIES AND WATERS OF LAKE ERIE

	Common Name	—Abundance—- Sp	Su	F	W
LOONS (Gaviidae)					
Gavia immer	common loon	U	R	U	O
Gavia stellata	red-throated loon	O		O	R
GREBES (Podicipedidae)					
Podiceps auritus	horned grebe	U		U	O
Podiceps grisegena	red-necked grebe	R		R	R
Podiceps nigricollis	eared grebe	R		R	R
Podilymbus podiceps	pied-billed grebe	C	U	C	O
CORMORANTS (Phalacrocoracidae)					
Phalacrocorax auritus	double-crested cormorant	C	C	C	R
HERONS (Ardeidae)					
Ardea albus	great egret [=common heron]	U	U	O	
Ardea herodias	great blue heron	C	C	C	O
Botaurus lentiginosus	American bittern	R	R	R	
Bubulcus ibis	cattle egret	R	R	R	
Butorides striatus	striated heron [=green-backed heron]	U	U	U	
Egretta thula	snowy egret	R	R	R	
Ixobrychus exilis	least bittern	R	R	R	
Nyctanassa violacea	yellow-crowned night-heron	R	R	R	
Nycticorax nycticorax	black-crowned night-heron	U	U	U	R
WATERFOWL: DUCKS, GEESE, & SWANS (Anatidae)					
Aiix sponsa	wood duck	C	C	C	R
Anas acuta	northern pintail	O	R	O	O
Anas americana	American wigeon	O	R	O	O
Anas clypeata	northern shoveler	O	R	O	R
Anas crecca	green-winged teal	O	R	O	R
Anas discors	blue-winged teal	U	U	U	R
Anas platyrhynchos	mallard	A	A	A	A
Anas rubripes	American black duck	C	U	C	C
Anas strepera	gadwall	U	R	U	O
Aythya affinis	lesser scaup	C	R	C	C
Aythya americana	redhead	U	R	U	O
Aythya collaris	ring-necked duck	U	R	U	O
Aythya marila	greater scaup	U		U	U
Aythya valisineria	canvasback	U		U	O
Branta canadensis	Canada goose	C	C	A	C
Bucephala albeola	bufflehead	C		C	U
Bucephala clangula	common goldeneye	C		C	C
Chen caerulescens	snow goose	R		O	R
Clangula hyemalis	oldsquaw	O		O	O
Cygnus columbianus	tundra swan [= whistling swan]	U		U	R
Cygnus olor	mute swan	R		R	R
Lophodytes cucullatus	hooded merganser	U	R	U	U
Melanitta fusca	white-winged scoter	O		O	U
Melannita nigra	black scoter	R		O	R
Melannita perspicillata	surf scoter	R		O	R
Mergus merganser	common merganser	O		O	U
Mergus serrator	red-breasted merganser	C	R	A	C
Oxyura jamaicensis	ruddy duck	C	R	C	R

AMERICAN VULTURES (Cathartidae)	Common Name	Sp	Su	F	W
		—Abundance—-			
Cathartes aura	turkey vulture	C	C	C	
BIRDS OF PREY: OSPREYS: (Accipitridae: Panioninae)					
Pandion haliaetus	osprey	U	R	U	
BIRDS OF PREY: HAWKS & EAGLES (Accipitridae: Accipitrinae)					
Accipiter cooperii	Cooper's hawk	U	U	U	U
Accipiter gentilis	northern goshawk	R		R	R
Accipiter striatus	sharp-shinned hawk	U	R	U	R
Buteo jamaicensis	red-tailed hawk	C	C	C	C
Buteo lagopus	rough-legged hawk	O		O	C
Buteo lineatus	red-shouldered hawk	U	R	U	R
Buteo platypterus	broad-winged hawk	U	R	U	
Circus cyaneus	northern harrier [= marsh hawk]	U	R	U	U
Falco columbarius	merlin	O		O	
Falco peregrinus	peregrine falcon	O	R	O	R
Falco sparverius	American kestrel [=sparrow hawk]	C	C	C	C
Haliaeetus leucocephalus	bald eagle	C	C	C	C
GALLINACEOUS BIRDS: PHEASANTS & QUAILS (Phasianidae)					
Colinus virginianus	northern bobwhite	R	R	R	R
Meleagris gallopavo	wild turkey	O	O	O	O
Phasianus colchicus	ring-necked pheasant	R	R	R	R
RAILS (Rallidae)					
Fulica americana	American coot	U	U	U	U
Gallinula chloropus	common moorhen	O	O	O	
Porzana carolina	sora	U	O	U	
Rallus elegans	king rail	R	R	R	
Rallus limicola	Virginia rail	O	O	O	
SHOREBIRDS: PLOVERS (Charadriidae)					
Charadrius melodus	piping plover	R	R	R	
Charadrius semipalmatus	semipalmated plover	U	U	U	
Charadrius vociferus	killdeer	C	C	C	R
Pluvialis dominica	American golden-plover	U	R	U	
Pluvialis squatarola	black-bellied plover	U	O	U	
SHOREBIRDS: SANDPIPERS & ALLIES (Scolopacidae)					
Actitis macularia	spotted sandpiper	C	C	C	
Arenaria interpres	ruddy turnstone	U	O	U	R
Bartramia longicauda	upland sandpiper	R	R	R	
Calidris alba	sanderling	U	O	U	
Calidris alpina	dunlin	A	O	C	R
Calidris canutus	red knot	O	O	O	
Calidris fuscicollis	white-rumped sandpiper	O	O	O	
Calidris himantopus	stilt sandpiper	O	O	O	
Calidris maritima	purple sandpiper			O	O
Calidris mauri	western sandpiper	O	U	U	
Calidris melanotos	pectoral sandpiper	C	U	C	
Calidris minutilla	least sandpiper	C	U	C	
Calidris pusilla	semipalmated sandpiper	C	U	C	
Catoptrophorus semipalmatus	willet	O	R	O	
Gallinago gallinago	common snipe	U	O	U	
Limnodrolus scolopaceus	long-billed dowitcher	R	R	U	
Limnodromus griseus	short-billed dowitcher	C	U	U	
Limosa fedo	*a* marbled godwit	R	R	O	
Phalaropus lobatus	red-necked phalarope	O	R	O	
Phalaropus tricolor	Wilson's phalarope	O	R	O	
Scolopax minor	American woodcock	U	U	U	
Tringa flavipes	lesser yellowlegs	U	O	U	

SHOREBIRDS: SANDPIPERS & ALLIES (cont'd)	Common Name	Sp	Su	F	W
Tringa melanoleuca	greater yellowlegs	U	O	U	
Tringa solitaria	solitary sandpiper	U	U	U	
TERNS (Laridae: Sterninae)					
Chlidonias niger	black tern	O	O	O	
Sterna caspia	Caspian tern	C	O	C	
Sterna forsteri	Forster's tern	C	O	C	R
Sterna hirundo	common tern	C	O	C	R
JAEGERS (Laridae: Stercorariinae)					
Stercorarius parasiticus	parasitic jaeger			O	R
GULLS (Laridae: Larinae)					
Larus argentatus	herring gull	A	C	A	A
Larus atricilla	laughing gull	R	O	O	R
Larus delawarensis	ring-billed gull	A	A	A	A
Larus fuscus	lesser black-backed gull	O		U	O
Larus glaucoides	Iceland gull	O		O	U
Larus hyperboreus	glaucous gull	O		O	U
Larus marinus	great black-backed gull	U	O	U	C
Larus minutus	little gull	O	R	O	R
Larus philadelphia	Bonaparte's gull	C	O	A	O
Larus pipixcan	Franklin's gull	R	R	O	R
Larus ridibundus	black-headed gull	R		R	R
Larus thayeri	Thayer's gull	O		O	U
Rissa tridactyla	black-legged kittiwake	R		O	O
DOVES (Columbidae)					
Columba livia	rock dove	A	A	A	A
Zenaida macroura	mourning dove	A	A	A	A
CUCKOOS (Cuculidae)					
Coccyzus americanus	yellow-billed cuckoo	U	U	U	
Coccyzus erythropthalmus	black-billed cuckoo	O	O	O	
OWLS (Strigidae)					
Aegolius acadicus	northern saw-whet owl	R	R	R	R
Asio flammeus	short-eared owl	R		O	O
Asio otus	long-eared owl	R		R	O
Bubo virginianus	great horned owl	C	C	C	C
Nyctea scandiaca	snowy owl	R		R	O
Otus asio	eastern screech-owl	C	C	C	C
Strix varia	barred owl	R	R	R	R
BARN-OWLS (Tyonnidae)					
Tyto alba	barn-owl	R	R	R	R
GOATSUCKERS & ALLIES (Caprimulgidae)					
Caprimulgus vociferus	whip-poor-will	O	R		
Chordeiles minor	common nighthawk	C	C	C	
HUMMINGBIRDS (Trochilidae)					
Archilochus colubris	ruby-throated hummingbird	C	C	C	
SWIFTS (Apodidae)					
Chaetura pelagica	chimney swift	C	C	C	
KINGFISHERS (Alcedinidae)					
Ceryle alcyon	belted kingfisher	C	C	C	U

WOODPECKERS (Picidae)	Common Name	Sp	Su	F	W
		—Abundance—-			
Colaptes auratus	northern flicker	C	C	C	O
Dryocopus pileatus	pileated woodpecker	R	R	R	R
Melanerpes carolinus	red-bellied woodpecker	U	U	U	U
Melanerpes erythrocephalus	red-headed woodpecker	U	U	U	R
Picoides pubescens	downy woodpecker	C	C	C	C
Picoides villosus	hairy woodpecker	C	C	C	C
Sphyrapicus varius	yellow-bellied sapsucker	U	R	U	R
	PERCHING BIRDS				
TYRANT FLYCATCHERS (Tyrannidae: Fluvicolinae)					
Contopus cooperi	olive-sided flycatcher	U	R	O	
Contopus virens	eastern wood-pewee	C	C	C	
Empidonax alnorum	alder flycatcher	O	R	O	
Empidonax flaviventris	yellow-bellied flycatcher	U	R	U	
Empidonax minimus	least flycatcher	C	U	U	
Empidonax traillii	willow flycatcher	C	C	O	
Empidonax virescens	Acadian flycatcher	C	C	U	
Sayornis phoebe	eastern phoebe	C	U	O	R
KINGBIRDS (Tyrannidae: Tyranninae)					
Myiarchus crinitus	great crested flycatcher	C	C	C	
Tyrannus tyrannus	eastern kingbird	C	C	C	
LARKS (Alaudidae)					
Eremophila alpestris	horned lark	C	C	C	C
SWALLOWS (Hirundinidae)					
Petrochelidon pyrrhonota	cliff swallow	O	R	O	
Hirundo rustica	barn swallow	C	C	C	
Progne subis	purple martin	C	C	C	
Riparia riparia	bank swallow	O	O	O	
Stelgidopteryx serripennis	northern rough-winged swallow	C	C	C	
Tachycineta bicolor	tree swallow	C	C	C	R
JAYS & CROWS (Corvidae)					
Corvus brachyrhynchos	American crow	C	C	C	C
Cyanocitta cristata	blue jay	A	A	A	A
CHICKADEES (Paridae)					
Baeolophus bicolor	tufted titmouse	C	C	C	C
Poecile atricapillus	black-capped chickadee	C	C	C	C
NUTHATCHES (Sittidae)					
Sitta canadensis	red-breasted nuthatch	U		U	U
Sitta carolinensis	white-breasted nuthatch	C	C	C	C
CREEPERS (Certhiidae)					
Certhia americana	brown creeper	U	R	U	O
WRENS (Troglodytidae)					
Cistothorus palustris	marsh wren	U	U	U	R
Cistothorus platensis	sedge wren	R	R	R	
Thryothorus ludovicianus	Carolina wren	O	O	O	O
Troglodytes aedon	house wren	C	C	C	
Troglodytes troglodytes	winter wren	C		O	O
GNATCATCHERS (Sylviidae)					
Polioptila caerulea	blue-gray gnatcatcher	C	C	C	

	Common Name	—Abundance—- Sp	Su	F	W
KINGLETS (Regulidae)					
Regulus calendula	ruby-crowned kinglet	C		C	O
Regulus satrapa	golden-crowned kinglet	C		C	O
THRUSHES (Turdidae)					
Catharus fuscescens	veery	U	O	U	
Catharus guttatus	hermit thrush	U	R	U	R
Catharus minimus	gray-cheeked thrush	U		U	
Catharus ustulatus	Swainson's thrush	U	R	U	
Hylocichla mustelina	wood thrush	C	C	C	
Sialia sailis	eastern bluebird	U	U	U	O
Turdus migratorius	American robin	A	A	A	U
MOCKINGBIRDS (Mimdae)					
Dumetella carolinensis	gray catbird	C	C	C	
Mimus polyglottos	northern mockingbird	R	R	R	R
Toxostoma rufum	brown thrasher	U	U	U	R
PIPITS (Motacillidae)					
Anthus spinoletta	water pipit	U		U	
WAXWINGS (Bombycillidae)					
Bombycilla cedrorum	cedar waxwing	C	C	C	U
SHRIKES (Laniidae)					
Lanius excubitor	northern shrike	R		R	O
Lanius ludovicianus	loggerhead shrike	R	R	R	
STARLINGS (Sturnidae)					
Sturnus vulgaris	European starling	A	A	A	A
VIREOS (Vireonidae)					
Vireo flavifrons	yellow-throated vireo	U	U	U	
Vireo gilvus	warbling vireo	C	C	C	
Vireo griseus	white-eyed vireo	O	O	O	
Vireo olivaceus	red-eyed vireo	C	C	C	
Vireo philadelphicus	Philadelphia vireo	O		O	
Vireo solitarius	blue-headed vireo [=solitary vireo]	U	O	U	
WOOD-WARBLERS (Parulidae)					
Dendroica caerulescens	black-throated blue warbler	U		U	
Dendroica castanea	bay-breasted warbler	C		C	
Dendroica cerulea	cerulean warbler	U	U	U	
Dendroica coronata	yellow-rumped warbler	C		C	O
Dendroica discolor	prairie warbler	R	R	R	
Dendroica dominica	yellow-throated warbler	O			
Dendroica fusca	Blackburnian warbler	U		U	
Dendroica magnolia	magnolia warbler	U		U	
Dendroica palmarum	palm warbler	U		U	
Dendroica pensylvanica	chestnut-sided warbler	U	O	U	
Dendroica petechia	yellow warbler	C	C	C	
Dendroica pinus	pine warbler	O		U	
Dendroica striata	blackpoll warbler	O		C	
Dendroica tigrina	Cape May warbler	U		U	
Dendroica virens	black-throated green warbler	U		U	
Geothlypis trichas	common yellowthroat	C	C	C	R
Icteria virens	yellow-breasted chat	U	U	U	
Mniotilta varia	black-and-white warbler	U	R	U	
Oporornis philadelphia	mourning warbler	O		R	
Parula americana	northern parula	U	R	O	
Protonotaria citrea	prothonotary warbler	O	O	O	
Seiurus aurocapillus	ovenbird	U	U	U	

	Common Name	Abundance Sp	Su	F	W
WOOD-WARBLERS (cont'd)					
Seiurus motacilla	Louisiana waterthrush	U	R	U	
Seiurus noveboracensis	northern waterthrush	U	R	U	
Setophaga ruticilla	American redstart	C	C	C	
Vermivora celata	orange-crowned warbler	O		O	R
Vermivora chrysoptera	golden-winged warbler	O	R	R	
Vermivora peregrina	Tennessee warbler	C		C	
Vermivora pinus	blue-winged warbler	U	U	U	
Vermivora ruficapilla	Nashville warbler	U		U	
Wilsonia canadensis	Canada warbler	U		U	
Wilsonia citrina	hooded warbler	U	O	U	
Wilsonia pusill	Wilson's warbler	U		U	
TANAGERS (Thraupidae)					
Piranga olivacea	scarlet tanager	U	U	U	
CARDINALS (Cardinalidae)					
Cardinalis cardinalis	northern cardinal	C	C	C	C
Passerina cyanea	indigo bunting	C	C	C	
Pheucticus ludovicianus	rose-breasted grosbeak	U	U	U	
Spiza americana	dickcissel	R	R	R	
AMERICAN SPARROWS (Emberizidae)					
Ammodramus caudacutus	saltmarsh sharp-tailed sparrow	R		O	
Ammodramus henslowii	Henslow's sparrow	R	R	R	
Ammodramus savannarum	grasshopper sparrow	O	U	O	
Calcarius lapponicus	Lapland longspur	O		O	O
Junco hyemalis	dark-eyed junco	C		C	C
Melospiza georgiana	swamp sparrow	U	O	U	O
Melospiza lincolnii	Lincoln's sparrow	U		U	R
Melospiza melodia	song sparrow	C	C	C	C
Passerculus sandwichensis	Savannah sparrow	U	C	U	R
Passerella iliaca	fox sparrow	U		U	R
Pipilo erythrophthalmus	eastern towhee [=rufous-sided towhee]	C	C	C	R
Plectrophenax nivalis	snow bunting	O		C	U
Pooecetes gramineus	vesper sparrow	U	U	U	
Spizella arborea	American tree sparrow	C		U	C
Spizella passerina	chipping sparrow	U	C	U	
Spizella pusilla	field sparrow	C	C	C	R
Zonotrichia albicollis	white-throated sparrow	C	R	C	U
Zonotrichia leucophrys	white-crowned sparrow	U		U	O
BLACKBIRDS & ORIOLES (Icteridae)					
Agelaius phoeniceus	red-winged blackbird	A	A	A	U
Dolichonyx oryzivorus	bobolink	U	C	U	
Euphagus carolinus	rusty blackbird	U		U	O
Icterus galbula	Baltimore oriole [=northern oriole]	C	C	C	
Icterus spurius	orchard oriole	U	U	O	
Molothrus ater	brown-headed cowbird	C	C	C	O
Quiscalus quiscula	common grackle	A	A	A	O
Sturnella magna	eastern meadowlark	C	C	C	O
Sturnella neglecta	western meadowlark	R	R	R	
FINCHES & ALLIES (Fringillidae)					
Carduelis flammea	common redpoll	O		R	O
Carduelis pinus	pine siskin	O	R	U	O
Carduelis tristis	American goldfinch	C	C	C	C
Carpodacus mexicanus	house finch	A	A	A	
Carpodacus purpureus	purple finch	U	O	U	U
Coccothraustes vespertinus	evening grosbeak	O		O	O

	Common Name	—Abundance—- Sp	Su	F	W
FINCHES & ALLIES (cont'd)					
Loxia curvirostra	red crossbill	R		R	R
Loxia leucoptera	white-winged crossbill	R		R	R
Pinicola enucleator	pine grosbeak	R		R	R
OLD WORLD SPARROWS (Passeridae)					
Passer domesticus	house sparrow	A	A	A	A

Seasonal Designations:
Sp – Spring (March-May)
Su – Summer (June-August)
F – Fall (September-November)
W – Winter (December-February)

Abundance Codes:
A – Abundant
C – Common
O – Occasional
U – Uncommon
R – Rare

APPENDIX F. AMPHIBIAN, REPTILIAN, AND MAMMALIAN FAUNA OF OLD WOMAN CREEK ESTUARY, WATERSHED, AND ADJACENT TRIBUTARIES AND WATERS OF LAKE ERIE

AMPHIBIANS

	Common Name	Location
NEWTS (Salamandridae)		
Notophthalmus viridescens	eastern newt	TR
MUDPUPPIES (Proteidae)		
Necturus maculosus	mudpuppy	LE,TR
MOLE SALAMANDERS (Ambystomatidae)		
Ambystoma jeffersonianum	Jefferson's salamander	TR
Ambystoma maculatum	spotted salamander	CK,TR
Ambystoma opacum	marbled salamander	TR
Ambystoma platineum	silvery salamander	TR
Ambystoma texanum	small-mouthed salamander	TR
Ambystoma tigrinum	tiger salamander	TR
Ambystoma hybrid mole salamander	CK,ES,TR	
LUNGLESS SALAMANDERS (Plethodontidae)		
Desmognathus fuscus	dusky salamander	CK,TR
Eurycea bislineata	two-lined salamander	CK,TR
Hemidactylium scutatum	4-toed salamander	TR
Plethodon cinereus	eastern redback salamander	CK,ES,TR
Plethodon glutinosus	slimy salamander	CK,ES,TR
Plethodon richmondi	ravine salamander	CK,ES,TR
Pseudotriton ruber	red salamander	CK
BUFONID TOADS (Bufonidae)		
Bufo americanus	American toad	CK,ES,TR
Bufo woodhousii fowleri	Fowler's toad	ES,TR
CRICKET FROGS AND TREEFROGS (Hylidae)		
Acris crepitans	northern cricket frog	TR
Hyla versicolor	gray treefrog	TR
Pseudacris crucifer crucifer	northern spring peeper	CK,ES,TR
Pseudacris triseriata	western chorus frog	ES,TR
RANID FROGS (Ranidae)		
Rana catesbeiana	bullfrog	CK,ES,TR
Rana clamitans melanota	green frog	CK,ES,TR
Rana palustris	pickerel frog	TR
Rana pipiens	northern leopard frog	ES,TR
Rana sylvatica	wood frog	TR

REPTILES

MUD AND MUSK TURTLES (Kinosternidae)		
Sternotherus odoratus	common musk turtle	TR
SNAPPING TURTLES (Chelydridae)		
Chelydra serpentina	snapping turtle	ES,TR
BOX AND WATER TURTLES (Emydidae)		
Chrysems picta marginata	midland painted turtle	CK,ES,TR
Clemmys guttata	spotted turtle	ES,TR
Emydoidea blandingii	Blanding's turtle	ES,TR
Graptemys geographica	common map turtle	ES,TR
Terrapene carolina carolina	eastern box turtle	CK,ES,TR

	Common Name	Location
SOFTSHELL TURTLES (Trionychidae)		
Apalone spiniferus	spiny softshell turtle	ES,TR
COLUBRID SNAKES (Colubridae)		
Clonophis kirtlandii	Kirtland's snake	TR
Coluber constrictor foxii	blue racer	CK,TR
Diadophis punctatus edwardsii	northern ring-neck snake	CK,TR
Elapha obsoleta obsoleta	black rat snake	CK,TR
Elapha vulpina gloydi	eastern fox snake	ES,TR
Heterodon platyrhinos	eastern hog-nosed snake	TR
Lampropeltis triangulum triangulum	eastern milk snake	ES,TR
Nerodia sipedon sipedon	northern water snake	CK,ES,TR
Opheodrys vernalis	smooth green snake	TR
Regina septemvittata	queen snake	CK,TR
Storeria dekayi dekayi	northern brown snake	ES,TR
Storeria dekayi wrightorum	midland brown snake	ES,TR
Thamnophis butleri	Butler's garter snake	ES,TR
Thamnophis sauritus	eastern ribbon snake	TR
Thamnophis sirtalis sirtalis	eastern garter snake	CK,ES,TR
Thamnophis sirtalis sirtalis	e. garter snake (melanistic)	ES,TR
VIPERS (Viperidea)		
Sistrurus catenatus	Massasauga rattlesnake	TR

MAMMALS

OPOSSUMS (Didelphidae)		
Didelphis virginiana	Virginia opossum	CK,ES,TR
SHREWS (Soricidae)		
Blarina brevicauda	northern short-tailed shrew	ES,TR
Cryptotis parva	least shrew	TR
Sorex cinereus	masked shrew	ES,TR
Sorex hoyi pygmy shrew	ES,TR	
MOLES (Talpidae)		
Parascalops breweri	hairy-tailed mole	ES,TR
Scalopus aquaticus	eastern mole	CK,ES,TR
VESPERTILIONID BATS (Vespertilionidae)		
Eptesicus fuscus	big brown bat	TR
Lsionycteris noctivagans	silver-haired bat	TR
Lasiurus borealis	red bat	TR
Lasiurus cinereus	hoary bat	TR
Myotis keenii	Keen's myotis or Keen's bat	TR
Myotis leibii	small-footed myotis	TR
Myotis lucifugus	little brown bat	ES,TR
Pipistrellus subflavus	e. pipistrelle or Georgian bat	TR
WOLVES & FOXES (Canidae)		
Canis latrans	coyote or brush wolf	ES,TR
Urocyon cinereoargenteus	gray fox	ES,TR
Vulpes vulpes	red fox	ES,TR
PROCYONIDS (Procyonidae)		
Procyon lotor	raccoon	CK,ES,TR
MUSTELIDS (Mustelidae)		
Mustela frenata	long-tailed weasel	ES,TR
Mustela nivalis	least weasel	TR
Mustela vison	mink	TR
Taxidea tasux	badger	TR
Mephitis mephitis	striped skunk	ES,TR

	Common Name	Location
HARES & RABBITS (Leporidae)		
Sylvilagus floridanus	eastern cottontail rabbit	CK,ES,TR
SQUIRRELS (Sciuridae)		
Glaucomys volans	southern flying squirrel	TR
Marmota monax	woodchuck or groundhog	CK,ES,TR
Sciurus carolinensis	gray squirrel	TR
Sciurus niger	fox squirrel	CK,ES,TR
Tamias striatus	eastern chipmunk	CK,ES,TR
Tamiasciurus hudsonicus	red squirrel	CK,ES,TR
BEAVERS (Castoridae)		
Castor canadensis	beaver	ES
RATS, MICE & VOLES (Muridae)		
Peromyscus leucopus	white-footed mouse	ES,TR
Peromyscus maniculatus	deer mouse	ES,TR
Microtus pennsylvanicus	meadow vole or field mouse	ES,TR
Ondatra zibethicus	muskrat	ES,TR
Synaptomys cooperi	southern bog lemming	TR
Mus musculus	house mouse	ES,TR
Rattus norvegicus	Norway rat or common rat	TR
JUMPING MICE (Dipodidae)		
Zapus hudsonius	meadow jumping mouse	ES,TR
DEER (Cervidae)		
Odocoileus virginianus	white-tailed deer	CK,ES,TR
BOVIDS (Bovidae)		
Bison bison	bison	CK

Location Codes**:**

CK – Old Woman Creek watershed upstream of the estuary
ES – Old Woman Creek estuary and contiguous uplands within State Nature Preserve
LE – Lake Erie, principally nearshore waters of eastern Erie County and western Lorain County, Ohio
TR – Tributary watersheds to Lake Erie other than Old Woman Creek, principally of eastern Erie County and western Lorain County, Ohio

13. Glossary

A

abiotic Non living or derived from non-living processes; factor contributing to an environment that is of a non-living nature.

ablation All processes by which snow and ice are lost from a glacier, floating ice, or snow cover, including melting, evaporation (**sublimation**), wind erosion, and **calving**.

AD Used as a prefix or suffix to a date, denoting the number of years after the beginning of the Christian calendar (*Anno Domini*).

adventitious roots Roots growing laterally from the stem rather than from the main root.

aerenchyma Tissue with large, air-filled cavities between the cells that are present in the stems and roots of certain aquatic plants that enables adequate gaseous exchange below water.

aerial Growing or borne above the ground or water; of, for, or by means of aircraft (e.g. aerial photography).

aggrading The building up or filling in of sediment through deposition.

allochthonous Material generated outside of a particular habit, but brought into that habitat.

alluvium Sediment deposited by a stream or running water.

anadromous Said of fishes and other aquatic animals that migrate from the open sea or an open lake into a tributary stream for the purpose of spawning.

anaerobic Capable of growing (metabolizing) in the absence of molecular (free) oxygen, obtaining energy from the breakdown of glucose sugar; condition in which molecular oxygen is absent from the environment.

anastomosing Said of a stream, leaf veins, protozoan structures, or blood vessels that are interwoven, braided, or netlike with numerous interconnections.

angiosperm Any member of the plant division Magnoliophyta, in which the seeds are enclosed in an ovary; consists of **dicotyledon** and **monocotyledon** plants.

annual Said of a plant living only one year; having a yearly periodicity.

anoxic A lack of oxygen.

anthropogenic Developed by human beings; man-made.

aqueous Of, or pertaining to water.

aquifer A body of rock that is sufficiently **permeable** to conduct **groundwater** and to yield economically significant quantities of water to springs and wells.

artifact Anything made by man or showing signs of human use; generally applied to tools, implements, and other objects of human manufacture.

atlatl A Mexican term for a spear throwing device; a stick with a hook at one end that fits into a depression in the base of a spear and is used to lengthen the thrower's arm, thus adding leverage and speed.

atlatl weights Stone objects fastened to the throwing stick for added mass.

autochthonous Material generated within a particular habitat and retained therein.

autotroph An organism that can manufacture its own organic requirements from inorganic materials; autotrophs are either phototrophic, energy being derived from **photosynthesis** where chlorophyll is present, or chemotrophic, energy being derived from inorganic oxidation where chlorophyll is absent; **primary producer**.

B

backshore The upper or inner, usually dry and narrow, zone of the shore or beach, lying between the normal high-water line and the upper limit of shore-zone processes; it is acted upon by waves or covered by water only during exceptionally severe storms or an unusually high **wind tide**. The backshore is essentially horizontal or slopes landward, and is divided from the **foreshore** by the crest of the most lakeward **berm**.

barrier beach A narrow, elongated sand ridge rising slightly above the high-water line and extending parallel with the shore, but separated from it by a **lagoon** or marsh.

bathymetry The description of the depths of a body of water, usually a map of the bottom where water depths are expressed as contours.

BC Used as a prefix or suffix to a date, denoting the number of years before the beginning of the Christian calendar.

bed The ground upon which any body of water rests, or the land covered by the waters of a stream, lake, or ocean; the smallest formal unit in a sequence of layered rocks.

benthos The plants and animals that live associated with the bottom margin of lakes, rivers, wetlands, or seas.

berm A low, impermanent, horizontal or landward-sloping bench or narrow terrace on the **backshore** of a beach, formed by material thrown up and deposited by storm waves; it is generally bounded on one side or the other by a beach ridge or beach scarp.

biface An initial stage in the manufacture of a stone artifact, such as a **projectile point,** that has been shaped by flaking on both sides to create an intermediate stage known as a preform.

bifurcated Said of a **projectile point** with a forked (Y-shaped) or divided base.

biomass The total mass of organic material of a species, or community of species, per unit area or volume; term used to express population density or **standing crop**.

biome A major ecological region or community characterized by distinctive life forms (e.g. tundra biome).

biota All living organisms of an area; the flora and fauna considered as a unit.

biovolume Volume of biological material in a specific organism or in a sample of water, sediment, or organic matter.

blade A term used by archaeologists in two ways: (1) a fragment of stone removed from a parent **core** to be used in the manufacture of an **artifact** ("blade and core industry") and (2) that portion of an artifact, usually a **projectile point** of knife, beyond the base.

blank A fragment of stone that has been worked roughly into shape, but which must further chipped to form the intended **artifact**.

boreal forest The geographic region immediately south of the Arctic **tundra** that is characterized by conifer (evergreen) woodlands.

bottomlands Low-lying, level land, usually highly fertile; a grassy lowland formed by the deposition of **alluvium** along the margins of a **watercourse**; an alluvial plain or flood plain.

BP Used as a suffix, denoting "before the present;" sometimes written **YBP** for "years before the present."

C

calving The breaking away of a mass or block of ice from a glacier.

canopy The uppermost continuous **stratum** of **foliage** in forest vegetation formed by the **crown**s of trees; tallest trees of the canopy form the overstory.

carrion feeder Any organism that feeds on dead animals; necrophagous feeder.

celt A prehistoric stone implement shaped like a chisel or ax head.

ceramics A term used by archaeologists for **pottery** objects made of clay.

chert A hard, compact, microcrystalline sedimentary rock, consisting dominantly of interlocking quartz crystals; material frequently used by prehistoric Indians to manufacture **projectile point**s.

chromosomes Threadlike linear strands of **DNA** and associated proteins in the nucleus of animal and plant cells that carries the genes and functions in the transmission of hereditary information.

clastic A rock or sediment composed of broken fragments of preexisting rock that has been cemented together by natural processes.

clay Individual mineral particles less than 0.002 mm in diameter.

CLEAR Acronym for Center for Lake Erie Area Research at The Ohio State University.

cleavage The property or tendency of a rock, mineral, or **soil** to split along predictable planes determined by the structure, texture, or crystal system of the material.

climax A stage in ecological development in which a community of organisms, especially plants, is stable and capable of perpetuating itself; climax community.

cloaca The common chamber into which the intestinal, urinary, and reproductive ducts open in lower vertebrates.

COD (**chemical oxygen demand**) The amount of oxygen used to break down the organic matter in samples using a strong chemical oxidant.

collenchyma Plant tissue in which the cell walls are thickened with cellulose, particularly at the corners, which provides support for stems and leaves.

community Any group of organisms comprising a number of different species that co-occur in the same **habitat** or area and interact through **trophic** and **spatial** relationships.

component An archaeological site, or any one of several cultures present at a site; a component generally has chronological and geographical connotations. The terms **focus** and **phase** have similar meanings.

conchoidal The shell-like shape of the fractured surface of stone **artifact**s made of **chert** or **flint**.

concretion A concentration or aggregation of chemical compounds and mineral matter (commonly calcium carbonate and iron oxides) in rock formations or soil forming grains or nodules of various sizes, shapes, hardness, and color, but usually subspherical to disk-shaped.

conductivity (**Specific Conductivity**) A measure of the ability of water to conduct an electrical current which is also a measure of the amount of ions dissolved in water. Specific Conductivity is conductivity adjusted to 25˚C.

cone-in-cone A layering in **sedimentary rocks**, generally limestone, which resembles a series of cones (apex down) one inside another.

conifer Cone-bearing, mostly large, evergreen trees that often form forests.

continental Characteristic of the interior of a continent, well removed from the climatic influence of the oceans.

cord-marked Pottery decoration produced by impressing twisted cord on the surface of soft clay.

core A piece of stone from which **flakes**, **blade**s, or **blank**s have been chipped away; artifacts shaped and modified from cores to serve as implements in their own right are called "core tools."

cork An outer layer of tissue in the stems and roots of certain woody plants, made up of cells with thick walls impregnated with **suberin,** that are dead when mature and impervious to water and air.

corm A modified underground stem, found in some **monocotyledon**s, which contains food reserves; often bulb-like in form, but has no fleshy scale leaves.

cotyledon A part of the plant embryo (seed) in the form of a specialized seed leaf that acts as a food storage organ and after germination functions as a true leaf.

crown The highest part or layer; typically said of the uppermost **foliage** of a tree.

cumulonimbus clouds Cumulus rain clouds with very dark, low, and often ragged bases, from which **precipitation** falls.

cumulus clouds Detached clouds, generally dense with sharp outlines that form rising mounds, domes, and towers which often resemble cauliflower and are brilliantly white where sunlit with dark, nearly horizontal bases.

cuticle In both plants and animals, a thin noncellular layer secreted by the **epidermis** which functions to prevent water loss, bacterial entry, admission of ultraviolet light, etc.

D

debitage Used by archaeologists to refer to waste material from the manufacture of artifacts (e.g. **chert** debitage).

deciduous Said of plants, particularly hardwood trees, that shed their leaves annually in autumn.

decomposer Any saprophytic organism, such as bacteria and fungi, that break down organic materials into simpler compounds and eventually into inorganic materials.

dendritic A pattern in streams or rivers where the stream (or river) and its tributaries resembles a branching tree.

desiccation A complete or nearly complete drying-out or drying-up, or a deprivation of moisture or of water not chemically combined; e.g. the loss of water from pore spaces of soil or sediment as a result of compaction.

detritus (1) A collective term for loose rock or mineral material mechanically weathered from older rocks and transported from its place of origin; (2) fragments of plants found in water or on the surface of **soil** (commonly fused together when soil is inundated by water).

diatactic The structure of a **varve** which shows a gradation in grain size from coarse below, up to fine above.

dicotyledon (**dicot**) Any **angiosperm** (flowering **vascular plant**) of the class Magnoliopsida; plants characterized by an embryo (seed) with two **cotyledon**s (specialized seed leaves that act as food storage organs and after germination functions as leaves); comprises over 150,000 species of highly developed plants (e.g. buttercups, oaks, buckwheats, roses, peas, mints, and composites).

differential borrowing The selective incorporation of traits by virtue of contact between people.

differential erosion Erosion that occurs at irregular or varying rates, caused by the differences in the resistance or hardness of the surface materials; softer and weaker rocks are rapidly worn away, whereas harder and more resistant rocks remain to form ridges, hills, and **escarpment**s.

differentiated Said of changes in cell, tissue, or organs during development that result in the appearance of a variety of structure and function found in the adult or other relatively stable phase of an organism's life history; increasing specialization of a cell as it approaches maturity.

diffusion (1) As a result of random movement of molecules, the dispersal of molecules from an area of higher concentration to an area of lower concentration; (2) the spread of a cultural trait from one area to another by means of contact between people.

DNA A nucleic acid that carries the genetic information in the cell and is capable of self-replication and synthesis of **RNA**; consists of two long chains of nucleotides twisted into a double helix and joined by hydrogen bonds between the complementary bases adenine and thymine or cytosine and guanine; sequence of nucleotides determines individual hereditary characteristics; deoxyribonucleic acid.

dolomite A **sedimentary rock** primarily consisting of calcium and magnesium carbonate.

downdraft A strong downward current of air.

dune A hill or ridge of wind-blown sand.

E

ecological niche The concept of the space occupied by a species, which includes both the physical space as well as the functional role of the species.

ecology The study of the interrelationships between living organisms and their environment.

ecosystem A **community** of organisms and their physical environment interacting as a unit.

ecotone The boundary or transition zone between adjacent communities or **biome**s.

emersed Said of a plant that rises above its substrate, such as an aquatic emergent plant.

entire margin (**or entire leaf**) Said of a leaf with a continuous smooth margin, not lobed or dentated (toothed).

eolian Said of features formed by wind action.

epidermal Pertaining to the outer layer of tissue; skin.

epidermis In plants, the tissue, usually one cell thick, that surrounds young roots, stems, and leaves; **epidermal** stem and leaf cells secrete a **cuticle**; epidermis of older roots and stems is often replaced by **cork** tissue.

epipelon The name given to organisms living on soft, fine-grained sediment.

erratic A rock fragment carried by glacial ice, or by floating ice and deposited at some distance from the outcrop from which it was derived (sizes range from pebbles to house-size blocks).

escarpment A long, more or less continuous cliff or relatively steep slope facing in one direction, breaking the continuity of the land by separating two levels of gently sloping surfaces, and produced by erosion or faulting.

estuarine Pertaining to, produced by, formed in, or inhabiting an **estuary**.

estuary The widened, commonly funnel-shaped, drowned mouth of a stream valley where stream water comes into contact with waters of a large, receiving body of water, such as the sea or a large lake, and where the effects of lunar tides or **wind tide**s are evident as these tides meet the current of the stream.

F

facultative Capable of functioning under varying environmental conditions; organism that assumes a particular mode of life, but is not restricted to that condition.

fast ice Any lake ice that forms along and remains attached to the coast.

festooned Ornamented with a carved or molded design, representing a chain or strip hanging loosely between two points.

fishery The fish population or stocks of a specific geographic region or body of water which are often subdivided into various **taxonomic**, **trophic**, or utilization categories.

flake A small, loose, flattened mass produced by chipping stones in the process of manufacturing **artifact**s; stone tools produced by chipping flakes from a **core** are called "flake tools."

flint A hard, homogeneous, **siliceous**, **sedimentary rock** considered to be a dark-gray or black variety of **chert**; artifacts made of this rock are smoother and show more perfect **conchoidal** fractures than chert.

floodplain Nearly level land, consisting of stream sediment (**alluvium**), that borders a stream and is subject to periodic flooding.

focus In archaeology, a group of **component**s that have similar traits, indicating a relationship.

foliage Collectively, the leaves of a plant.

forb Any broad-leaved, **herbaceous plant**, other than a grass, especially one growing in a field, prairie, or meadow.

foreshore The lower or outer, gradually lakeward-sloping zone of the shore or beach, lying between the crest of the most lakeward **berm** of the **backshore** and the normal low-water line; it is the portion of the beach normally washed by waves.

fossil The remains of a once living organism preserved in the rock strata.

fossil record The remains of organisms or traces of their existence, such as mastodon carcasses preserved in a bog or casts of marine shells in limestone, that form a history of the development of life from its origin on Earth. The record is incomplete, due to the comparative rarity with which fossils are formed, but provides evidence of evolution having taken place, particularly where long series of a particular form can be traced over an extended time period.

freshwater An aquatic environment such as streams and lakes, where there is comparatively little dissolved mineral matter and which results directly from **precipitation** (rain and snow), as opposed to salt water of the oceans and seas.

friable Said of a rock, mineral, or **soil** that crumbles naturally or is easily broken, pulverized, or reduced to powder.

frustule The hard, silica-containing wall of a diatom.

fungus (pl. **fungi**) A plant-like organism that may be unicellular or made up of tubular filaments and lacks chlorophyll; they live entirely as **saprophyte**s or parasites.

fyke net A long bag-shaped net held open with hoops used to catch fish.

G

gall An abnormal swelling or growth of plant tissue caused by insects, mites, microorganisms, fungi, or external injury.

gamete A reproductive cell having the **haploid** number of **chromosomes**, especially a mature sperm or egg capable of fusing with a gamete of the opposite sex to produce the fertilized egg.

gas exchange The transfer of gases between an organism and the environment. In **respiration** oxygen is taken into an animal or plant and carbon dioxide is given out. In **photosynthesis** carbon dioxide is required by plants and oxygen is given off. In plants, and some lower animals, gas exchange takes place by **diffusion**, while in higher animals special respiratory surfaces have developed.

gene A hereditary unit that occupies a specific location on **chromosome**s and determines a particular characteristic in an organism: genes exist in a number of different forms and can undergo mutation.

geochemistry The study of the distribution and amounts of the chemical elements in minerals, ores, rocks, **soil**s, water, and the atmosphere, and the study of the circulation of the elements in nature, on the basis of the properties of their atoms and ions.

geological time scale A chronological listing of geologic time periods, generally with the oldest period at the bottom of the list (see diagram for Ohio geologic time scale on page 13-7).

germ cell An egg or sperm cell.

glaciolacustrine The suspended material brought by meltwater streams flowing into lakes bordering glaciers.

gleization A process in saturated soils which involves the reduction of iron yielding **concretion**s and a **mottled** appearance or removal of iron by leaching.

gleyed Said of a soil that has undergone **gleization** which is manifested by neutral gray, bluish, or greenish colors throughout the **soil matrix** or in mottles (spots or streaks) among other soil colors.

gravel Unconsolidated, natural accumulation of rounded rock fragments larger than **sand** (>2.0 mm in diameter).

greenhouse effect The warming of the Earth's atmosphere because it is transparent to incoming sunlight and opaque to heat radiated from Earth; opacity is increased by added amounts of carbon dioxide, water vapor, methane, and dust in the atmosphere.

groundwater Subsurface water that is below the **water table** (within the **zone of saturation**), including underground streams.

gust A rapid, brief increase in the strength of the wind relative to the mean strength during a specific period of time.

H

habitat The local environment occupied by an organism.

hail Hard pellets of ice of various sizes and shapes, more or less transparent, which fall from **cumulonimbus clouds** and are often associated with **thunderstorms**.

haploid Having the same number of sets of **chromosomes** as a **germ cell** or half as many as a **somatic cell**.

hardpan A general term for a relatively hard, **impervious**, and often clayey layer of soil lying at or just below the surface produced by the compaction or cementation of soil particles by organic matter, silica, iron oxides, or calcium carbonate.

hearth The floor of a fireplace, located inside or outside a dwelling, generally paved or lined with stone.

herbaceous plant Any green vascular plant of low stature whose stem does not become woody, either annual or grows from a perennial root or **rhizome**.

horizon A layer of **soil**, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes; the major horizons in descending order: O, A, B, C, and R.

humus The generally dark, relatively stable, part of the organic matter in soil, so well decomposed that the original sources can not be identified.

hydric soil A soil that is saturated, flooded, or ponded long enough during the growing season to develop **anaerobic** conditions in the upper part.

hydrophyte Plant, usually a **macrophyte**, that grows in water or on a **substrate** that is at least periodically deficient in oxygen as a result of excessive water content.

hypertrophy Excessive growth or development of an organ or tissue; term also applied to lakes with excessive nutrients.

Hypsithermal A postglacial interval of time (8,000 to 6,000 **YBP**) when the world's annual temperature was several degrees warmer than at present; also known as the Climatic Optimum or Thermal Maximum.

hypsographic curve A cumulative-frequency profile representing the statistical distribution of the relative areas of the Earth's surface (land and lakefloor) at various elevations above, or depths below, a given datum plane, e.g. lake level.

I

IGLD International Great Lakes Datum (IGLD 1985); reference plane used by American and Canadian agencies for measuring water levels in the Great Lakes, zero elevation equivalent to mean water level in the Gulf of St. Lawrence at Rimouski, Quebec, 1985.

impervious Said of rock, sediment, or **soil** that is incapable of transmitting a fluid; impermeable.

in situ In place; in archaeology, biology and geology, a term to indicate that an artifact, organism, or object is in the place in which it was originally deposited or lived.

Years before present, in millions of years	Eras and duration in years	Periods and and duration in years	Area of outcrop in Ohio and principal rock types
	CENOZOIC 66+ million	QUATERNARY 1.5-2 million	northwestern 2/3 of Ohio—unconsolidated sand, gravel, clay
1.6		*TERTIARY 62.5 million*	*NOT PRESENT IN OHIO*
66.4	*MESOZOIC 179 million*	*CRETACEOUS 78 million*	
144		*JURASSIC 64 million*	
208		*TRIASSIC 37 million*	
245	PALEOZOIC 325 million	PERMIAN 41 million	southeastern Ohio—shale, sandstone, coal, clay, limestone
286		PENNSYLVANIAN 34 million	eastern Ohio—shale, sandstone, coal, clay, limestone
320		MISSISSIPPIAN 40 million	east-central, northeastern, and northwestern-most Ohio—shale, sandstone, limestone
360		DEVONIAN 48 million	central, northeastern, and northwestern Ohio—shale, limestone
408		SILURIAN 30 million	western Ohio—dolomite, limestone, shale
438		ORDOVICIAN 67 million	southwestern Ohio—shale, limestone
505		CAMBRIAN 65 million	NOT EXPOSED IN OHIO — Cambrian sandstones, shales, and carbonates and Precambrian sedimentary, igneous, and metamorphic rocks present in subsurface
570	PRECAMBRIAN 3,400 million		

Geologic Time Scale for the rocks exposed in Ohio (from Feldmann and Hackathorn 1966).

interstices Openings or spaces in rock or **soil**, particularly spaces between solid particles.

isostatic rebound The upward adjustment of the Earth's crust to reestablish equilibrium following an unloading of glacial ice that had previously depressed the land surface.

J

joint A fracture or parting in a rock, without displacement; joints often occur as a parallel series of fractures.

JTU Jackson Turbidity Unit; see **turbidity**.

K

kame A low mound, knob, hummock, or short irregular ridge, composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier.

kame terrace A terracelike ridge consisting of stratified sand and gravel formed as a deposit between a melting glacier and a higher valley wall.

Kjeldahl A chemical method used to determine the quantity of organic and ammonia nitrogen in a water or sediment sample.

krummholz The gnarled, twisted, and supine growth form of trees exposed to continuous strong, often cold winds.

L

lacuna An air space or cavity in the stems of certain plants.

lacustrine Pertaining to, produced by, formed in, or inhabiting a lake.

lagoon A shallow stretch of lake water near or communicating with the lake and partly or completely separated from it by a low, narrow, elongated strip of land, such as a **barrier beach**, sandbar, or spit.

lanceolate Lance-shaped, tapering from a rounded base toward an apex; said of a narrow, tapering **projectile point**.

larva (pl. **larvae**) The newly hatched, earliest stage of any of various animals capable of acquiring its own nourishment, that undergoes metamorphosis, differing markedly in form and appearance from the adult.

lead Any fracture, water opening, or long narrow strip of lake water through ice (especially **pack ice**) which is navigable by surface vessels.

lenticel A small pore found on the surface of stems and roots in higher plants; lenticels usually arise below a **stoma** of the original **epidermis**, where loose packing tissue (**cork**) becomes waterproofed with a fatty substance (**suberin**), leaving large intercellular spaces for gas exchange.

lichen A biological association composed of an alga and a fungus; because of low nutrient requirements, lichens can colonize barren environments (e.g. bare rock) and as such are significant **pioneer species** in **succession**.

lignified stem A cellulose plant stem impregnated with **lignin**, resulting in the formation of wood.

lignin A complex, non-carbohydrate polymer found in the cell walls of woody plants, which functions to provide stiffening to the cell and bark fibers; since lignin forms an impermeable barrier, the cells are dead.

limestone A **sedimentary rock** primarily consisting of calcium carbonate.

limnetic Pertaining to organisms inhabiting open waters of lakes; said of conditions in the open waters of lakes and inland seas.

limnology The science that deals with life in inland waters and all factors which influence it; the study of lakes and streams.

lithic Rock; objects or artifacts made of stone.

lithification The conversion of a newly deposited, unconsolidated sediment into a coherent, solid rock, involving processes such as cementation, compaction, **desiccation**, and crystallization; conversion may occur concurrent with, soon after, or long after deposition.

lithology Study of the description of rocks.

Little Ice Age A cool climatic interval following the warm **Medieval** period (16th to 18th centuries **AD**).

loam A rich, **permeable soil** composed of a **friable** mixture of relatively equal proportions of **sand**, **silt**, and **clay** as well as organic matter (**humus**); specifically, sand (23-52%), silt (28-50%), and clay (7-27%).

LWD Low Water Datum; datum plane used for National Oceanic and Atmospheric Administration navigational charts of Lake Erie; equivalent to 173.49 m (569.2 feet) above International Great Lakes Datum (IGLD 1985) or 173.80 m (570.2 feet) above Mean Sea Level (MLS 1929).

M

macrophyte Any plant that can be readily observed without the aid of optical magnification, including all vascular plants and large algae (macroalgae).

magnetite An iron oxide mineral that forms **sand** sized particles in the beaches along the Lake Erie shoreline.

mano A Spanish term for an **artifact** used in the hand for grinding grain, seeds, or rock material on stone slabs (**metate**) to obtain a meal or pigment.

Medieval Relating or belonging to the Middle Ages (period in European history between antiquity and the Renaissance, often dated from **AD** 500 to 1500).

metate A Mexican term for slabs of stone on which grain was placed to grind by a **mano**.

midden A deposit of refuse material; often called a kitchen midden.

mitigation Any action which reduces or eliminates adverse effects which would result from a proposed action (e.g. highway construction); mitigation may include project redesign or relocation, data recovery and documentation, etc.

MLS Mean Sea Level; datum plane used for U.S. Geological Survey topographic maps, mean tide level at New York City, 1929.

monocotyledon (**monocot**) Any **angiosperm** (flowering **vascular plant**) of the class Liliopsida; plants characterized by an embryo (seed) with a single **cotyledon** (specialized seed leaf that acts as a food storage organ and after germination functions as a leaf); comprises over 75,000 of plants (e.g. grasses, sedges, rushes, lilies, irises, and orchids).

moraine A mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly **till**, deposited chiefly by direct action of glacial ice, in a variety of topographic landforms that are largely independent of control by the surface on which the drift lies.

morph Form, as in the "red morph" when referring to a color variant in a group of plants or animals.

morphological Pertaining to the shape, form, and general appearance of an organism or geological feature.

mottled Said of a **soil** or rock that is irregularly marked with spots of different colors that vary in size, indicating in soils, poor drainage and lack of aeration.

multi-component site An archaeological site showing evidence (**artifact**s) of occupation by more than one culture, each with distinct chronological and geographical connotations; site with artifacts from multiple time periods.

N

nannoplankton Small plankton that generally pass through a standard plankton net (10 to 50µm).

Neoglaciation Modest readvances of mountain and polar glaciers following the **Hypsithermal** interval and during the **Little Ice Age** interval of the late Holocene epoch.

netsinker A stone weight that is used to sink the bottom edge of a fishing net.

neuston Community of plants and animals living associated with the water's surface; epineuston live on the surface film and hyponeuston live at the underside of it.

NOAA Acronym for National Oceanic and Atmospheric Administration within the United States Department of Commerce.

nomadic Said of a group of people who have no fixed home and move according to the seasons from place to place in search of food, water, and grazing land.

NTU Nephelometric Turbidity Units; see **turbidity**.

O

obligate Essential or necessary; unable to exist in any other environment, state, or relationship.

ODNR Acronym for Ohio Department of Natural Resources.

OEPA Acronym for Ohio Environmental Protection Agency.

omnivore An organism feeding on both animals and plants.

open water (1) A relatively large area of freely navigable water in an ice-filled region, specifically water in which the concentration of floating ice is less than 10%; (2) lake water that remains unfrozen or uncovered by ice during the winter (3) lake water that is free of emergent vegetation and dense masses of submerged vegetation at shallow depths.

opposed rim The rim of a pottery vessel that is characterized by a contrasting or counterbalanced design.

ossuary A container or receptacle, such as an urn or a vault, for holding the bones of the dead.

P

pack ice Any area of lake ice (other than **fast ice**) composed of a heterogeneous mixture of ice of varying sizes and ages and formed by the jamming or crushing together of pieces of floating ice.

pagan Said of a people who adhere to a religion that does not acknowledge the God of Judaism, Christianity, or Islam; heathen.

papilla (pl**. papillae**) A small, nipple-like eminence or projection from the surface of a structure, sometimes containing sensory apparatus.

PAR (Photosynthetic Active Radiation) A measurement of the wavelengths of light that can be used in photosynthesis.

parent material The disintegrated and partly weathered bedrock or other geologic material from which a **soil** has formed.

pathology The study of the nature of disease and its causes, processes, development, and consequences; anatomic or functional manifestations of a disease.

perennial Said of a plant that persists for several years with a period of growth each year.

permeable Said of a porous rock, sediment, or soil that has the capacity for easily transmitting a fluid.

phase In archaeology, remains or artifacts of what is presumed to be a single people at a given period in their history.

photic zone That potion of a lake where light intensity is sufficient to accommodate plant growth (typically ≥ 1% of surface light).

photomicrograph A picture taken through a microscope, frequently through an electron or a scanning electron microscope.

photosynthesis The process that takes place within certain cells of green plants by which simple sugars are manufactured from carbon dioxide, water, and mineral nutrients with the aid of chlorophyll in the presence of light.

phreatic divide An underground feature that separates one basin of **groundwater** flow from another.

phylogenetic Relating to or based on evolutionary development of a plant or animal.

pioneer species Plant or animal that colonizes a previously uninhabited site (e.g. a **lichen** on a rock).

pistil The flask-shaped, female reproductive organ of a flower, consisting of a stalk (style) that connects an enlarged base where seeds are produced (ovary) to a pollen-receiving tip (stigma).

pistillate flower A flower that contains only female reproductive organs.

pleuston Aquatic organism that lives suspended at the water surface by their own buoyancy, normally positioned partly in the water and partly in the air.

plowzone The portion of the **soil** that is disturbed (mixed) by agricultural practices, usually extending to a depth of 0.2 to 0.5 m and roughly corresponding to the O and A soil **horizon**s.

pollen A grain (male spore) produced in higher plants by the **stamen**'s anther.

population All individuals of one species occupying a defined area and usually isolated to some degree from other similar groups.

post mold The remains, or discoloration of the **soil**, left after the decay of a wooden post that was placed in the ground to form a defensive structure or support a dwelling.

pottery Ware, such as vessels, vases, pots, bowls, or plates, shaped from moist clay and hardened or dried by heat, generally fired (baked) in a kiln.

polynya Any nonlinear opening enclosed in ice, especially a large expanse of water other than a **lead**, surrounded by lake or sea ice, but not large enough to be called **open water**; commonly found off the mouth of a large river.

precipitation In meteorology, any **aqueous** deposit, in liquid or solid form, derived from the atmosphere.

primary producer An organism capable of manufacturing its own food from inorganic raw materials; **autotroph**.

primary production The production of organic material from inorganic sources by an **autotroph**; rate of photosynthetic carbon fixation by plants and bacteria.

production In **limnology**, the growth of organisms in a body of water expressed in amount of growth per unit time per unit area or volume of the body of water.

productivity (**productive**) In **limnology**, a general term for the organic fertility of a body of water; relative capacity of a body of water to produce organisms or a particular organism.

projectile point The point of any weapon such as an arrow, lance, or spear.

promontory A high ridge of land or rock, generally jutting out into a body of water or overlooking a lowland; a headland.

propagation Multiplication or increase in the **population** of an organism, as by natural reproduction.

Q

quadrat A delimited area for sampling flora or fauna; usually taken randomly and typically consisting of a 1-m square frame.

quarry Open workings in the Earth's surface, usually for the extraction of stone.

Quaternary The second period of the Cenozoic Era, following the Tertiary. This period began about 2 million years ago and extends to the present; it consists of two grossly unequal epochs: the Pleistocene (ice age), up to 8,000 years ago, and the Holocene since that time.

R

radiocarbon dating (**carbon-14 dating**) A method of determining an age in years by measuring the concentration of carbon-14 (radioactive isotope) remaining in a sample of a formerly living organism which is based on the assumption that assimilation of carbon-14 abruptly ceases on the death of the organism. Carbon-14 has a half life of about 5650 years, thus the method is most useful in determining ages in the range of 500 to 70,000 years.

relief The elevations or general unevenness of the land surface; more strictly, the vertical difference in elevation between the hilltops and valleys of a given region.

respiration A process by which **gas exchange**, oxygen and carbon dioxide, takes place between an organism and the surrounding environment.

rhizome An underground plant stem that generally lies horizontally and that is often enlarged in order to store food.

rill A very small brook, trickling stream of water, or the small channel made by the stream.

riverine Pertaining to, produced by, formed in, or inhabiting a river.

RNA A constituent of all living cells, consisting of a long, usually single-stranded chain of alternating phosphate and ribose units with the bases adenine, guanine, cytosine, and uracil bonded to the ribose; structure and base sequence of RNA are determinants of protein synthesis and transmission of genetic information; ribonucleic acid.

S

saltate Sediment movement in streams where the particles move in short quick jumps instead of long gradual steady movements.

sand Individual rock or mineral fragments (particles) ranging in size 0.05 to 2.0 mm in diameter.

sandstone A **sedimentary rock** that originally formed from sand–sized particles.

saprophyte Any organism, especially fungi or bacteria, that grows on and derives its nourishment from dead or decaying organic matter; **decomposer**.

scraper A stone **artifact** used in the scraping of hides or soft materials; term is often modified by a prefix indicating the shape of the artifact (e.g. spurred end scraper and "humped-backed" scraper).

sedimentary rocks Bedrock formed from the deposition of mineral particles that have settled out of water.

seed beads Small, generally white, glass beads that were often sewn on clothing or other fabric items as decoration.

seiche The free oscillation of water resulting from either wind activity or barometric pressure differences on major water bodies.

SEM Acronym for scanning electron microscope.

serrated Possessing a notched or saw-tooth edge.

serrulate Bearing fine notches or minute teeth.

shale A **sedimentary rock** that originally formed from clay, silt or mud.

sherd A fragment of a clay vessel; potsherd.

shoots The part of a vascular plant above the ground, consisting of stem and leaves.

siliceous Said of rocks containing abundant silica (chemically resistant dioxide of silicon, SiO_2).

silt Individual mineral particles that range in size from 0.002 to 0.05 mm in diameter.

SNP Acronym for State Nature Preserve. A component of the Division of Natural Areas and Preserves, **ODNR**.

soil A natural, material on the Earth's surface that supports plants and that has properties resulting from the integrated effect of climate and living matter acting on geologic **parent material**, as conditioned by **relief** over a period of time.

soil aggregates Numerous soil particles held together in a single mass or cluster; natural soil aggregates, such as crumbs, blocks, or prisms, are known as peds, whereas, aggregates produced by tillage or logging are called clods.

soil consistence The feel and ease with which a lump of soil can be hand crushed, including descriptive forms such as loose (falls apart, noncoherent). friable (crumbles, crushes easily), firm (resistant, crushes with moderate pressure), plastic (deforms readily, forms rolls), sticky (adheres to other material when wet), hard (difficult to break when dry), soft (readily breaks into grains or powder when dry), and cemented (hard and brittle when wet or dry).

soil matrix The natural soil material of both mineral and organic matter; matrix color refers to the predominant color of a particular soil horizon.

soil profile A vertical section of soil through all of its **horizon**s and extending into the **parent material**.

soil structure The arrangement of the individual soil particles into clusters that are separated from adjoining aggregates and have properties that are unlike those of non-aggregated particles, including structural forms such as platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), granular (small clusters), massive (particles adhering without any regular **cleavage**, as in **hardpan**), and structureless (single grains, as in **dune** sand).

soil texture The relative proportions of **sand**, **silt**, and **clay** particles in a mass of soil.

solum The upper part of the **soil profile**, above the **parent material**, in which the processes of soil formation are active and generally consists of the A and B **horizon**s (true soil); living roots of plants and burrowing animals are largely confined to this part of the soil.

somatic cell Any cell of a plant or an animal other than a **germ cell**; body cell.

spatial Pertaining to, involving, or having space; relating to a particular area.

specific heat The ratio of the quantity of heat required to raise the temperature of a given mass of a substance through a given range, to the heat required to raise the temperature of an equal mass of water through the same temperature range (approximately the heat required to raise the temperature of 1 cubic centimeter (cc) of a substance 1° C).

spermatophore A structure produced in the **cloaca** of a male consisting of a capsule or compact mass of **spermatozoa** extruded by certain invertebrates and primitive vertebrates and directly transferred to the reproductive parts of the female.

spermatozoa A sperm cell; the mature fertilizing **gamete** of a male organism, usually consisting of a round or cylindrical nucleated cell, a short neck, and a thin, motile tail.

stalk The stem of a leaf or flower.

stamen The male organ of a flower, consisting of a slender stalk (filament) and a knob-like, pollen-bearing tip (anther).

standing crop The total mass of organisms comprising all or part of a **population,** or other specified group, within a given area, measured as volume, mass, or energy (calories); **Biomass**.

stemmed Said of a **projectile point** that possesses an indented shank.

stoma (pl. **stomata**) An opening in the epidermis of leaves, and some stems, that enables **gas exchange**.

stratified Said of a lake or a sedimentary deposit that possesses horizontally formed layers.

stratum (pl. **strata**) A layer; in geology, a tabular or sheetlike layer of sedimentary rock; **bed**.

suberin A complex of fatty substances present in the walls of **cork** tissue which makes the tissue waterproof and resistant to decay.

sublimation The process by which a solid substance vaporizes without passing through a liquid stage.

subsistence economy An economic system (activities in which humans acquire food and satisfy other wants) in which a family or small band engages in both the production and limited processing required for local consumption without the benefit of trade or exchange with other groups.

subsoil The soil B **horizon**; roughly the part of the **solum** below the **plowzone**, where dark materials leached from the A horizon accumulate.

substrate The substance or base on which an organism lives and grows, or the surface to which a fixed organism is attached (e.g. soil, rock, water, leaf tissue, etc.).

succession In ecology, the gradual and orderly process of **ecosystem** development brought about by progressive changes in **community** composition leading to a stable **climax community** in a particular geographic region.

swamp forest Wet spongy ground, saturated or intermittently inundated by standing water, typically dominated by **woody plant**s, but without a significant accumulation of surface peat.

T

taxon (pl. **taxa**) A named group of organisms of any rank (i.e. species, genera, family, order, class, phylum, or division).

taxonomic Relating to the theory and practice of classifying plants and animals.

temper Sand, grit, plant fibers, and other materials mixed with the clay of a vessel to prevent it from cracking during drying process.

temperate Characterized by moderate temperatures, weather, or climate; neither hot nor cold.

thunderstorm Sudden electrical discharges in the atmosphere, manifested by lightning flashes and sharp rumbling sounds; normally associated with **cumulonimbus clouds**, heavy rainfall, and less frequently **hail**.

till Unsorted and unstratified drift, generally unconsolidated, deposited directly by and under a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

tool-impressed Said of pottery with decoration produced by impressing a stone tool onto the surface of the soft clay.

topsoil The soil A **horizon**; roughly the upper part of the **solum** within the **plowzone**.

trade beads Glass beads manufactured in Europe during 16th to 18th centuries that were used as barter items for trade with native North American peoples.

transpiration Expulsion of excess water vapor from the inside of a leaf to the outside atmosphere, generally through evaporation at the leaf surface, via **stomata** and **lenticel**s.

trophic Pertaining to an organism's stage or level of nutrition in a food chain.

tundra A treeless area between the icecap and the **boreal forest** tree line of Arctic regions, having a permanently frozen subsoil and supporting low-growing vegetation such as **lichen**s, mosses, grasses, and stunted shrubs.

turbidity A measure of particles suspended in the water; measured as Jackson Turbidity Units (**JTU**) or Nephelometric Turbidity Units (**NTU**) depending on the apparatus used (1 JTU=1 NTU).

tussock A raised clump of grasses or sedges growing in a wetland.

U

unconformity A substantial gap in the geologic record of rocks caused by uplifting or erosion.

understory The foliage layer lying beneath and shaded by the main **canopy** of a forest, mainly seedlings, shrubs, and herbs; sometimes distinguished from the groundstory or lowest layer of vegetation (i.e. ground cover) in a stratified woodland or forest community.

undifferentiated Said of indifferent cells, tissues, or structures which show a lack of specialization; simple; homogeneous.

univorous Feeding on only one type of food.

unstemmed Said of a **projectile point** that lacks an indented shank.

updraft An upward current of air.

USACE Acronym for United States Army Corps of Engineers.

USEPA Acronym for United States Environmental Protection Agency.

V

varve A sequence of layers deposited by a glacier meltwater stream. Each varve consists of a coarse light colored summer layer grading into a thin fine dark winter layer.

vascular Said of vessels which conduct fluid (e.g. blood in mammals and water in plants).

vascular bundles A structure in **vascular plant**s that runs up through the roots, into the stems, and out into the leaves, and whose function is transport of water and dissolved organic solutes within a plant.

vascular plant A plant with a well-developed conductive system and structural differentiation; the majority of visible terrestrial plants are vascular.

vermilion A bright red mercuric sulfide used as a pigment.

W

water table The upper surface of unconfined groundwater (atmospheric pressure); top of the **zone of saturation** where it meets the **zone of aeration**.

watercourse A natural, well-defined channel produced a definite flow of water.

watershed The region drained by a particular stream system; area contributing water to a stream, lake, or other body of water; drainage basin or catchment.

wetland Lands where saturation with water determines the nature of soil development and the types of plant and animal communities living in the soil and on its surface; environment transitional between terrestrial and aquatic systems where the water table is at or near the surface of the soil or is covered by shallow water; characterized by the presence of **hydrophyte**s and **hydric soil**s.

wigwam An Indian dwelling of the Great Lakes region commonly having an arched or conical framework of poles overlaid with bark, hides, or rush mats.

wind set-up The vertical difference in water level between the leeward and windward sides of a body of water, caused by the force of wind on the water surface; also measured as the rise from the still-water level on the leeward side of the body of water.

wind tide Vertical rise of the still-water level on the leeward side of a body of water, caused by the force of wind on the surface of the water.

windrow An accumulation of material formed naturally by the wind (e.g. pile of ice at the shoreline).

woody plant A **perennial** plant having a secondarily thickened **lignified stem**.

X

xeric A habitat characterized by a low supply of moisture and the organisms that exist in such a habitat.

xylem A woody plant tissue that is **vascular** in function, enabling transport of water with dissolved minerals within a plant, usually upward.

xylem vessel An empty tube formed from longitudinal fusion of cells with strong walls, whose function is transport of water for **transpiration**; vessels are aggregated into **xylem** tissue within the **vascular bundles** of **angiosperm**s.

Y

YBP Used as a suffix, denoting, "years before the present."

yield The amount of organic matter (plant and animal) produced by a body of water, either naturally or under management.

Z

zone of aeration An underground zone, containing air under atmospheric pressure, extending down from the land surface to the **water table**.

zone of saturation An underground zone, below the **water table**, in which all of the **interstices** are filled with water under pressure greater than that of the atmosphere.

zooplankton A collective name for minute planktonic animals, such as microcrustacean, rotifers, and protozoans, that float in the water.

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Notes

Notes

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Old Woman Creek State Nature Preserve and National Estuarine Research Reserve

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