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.

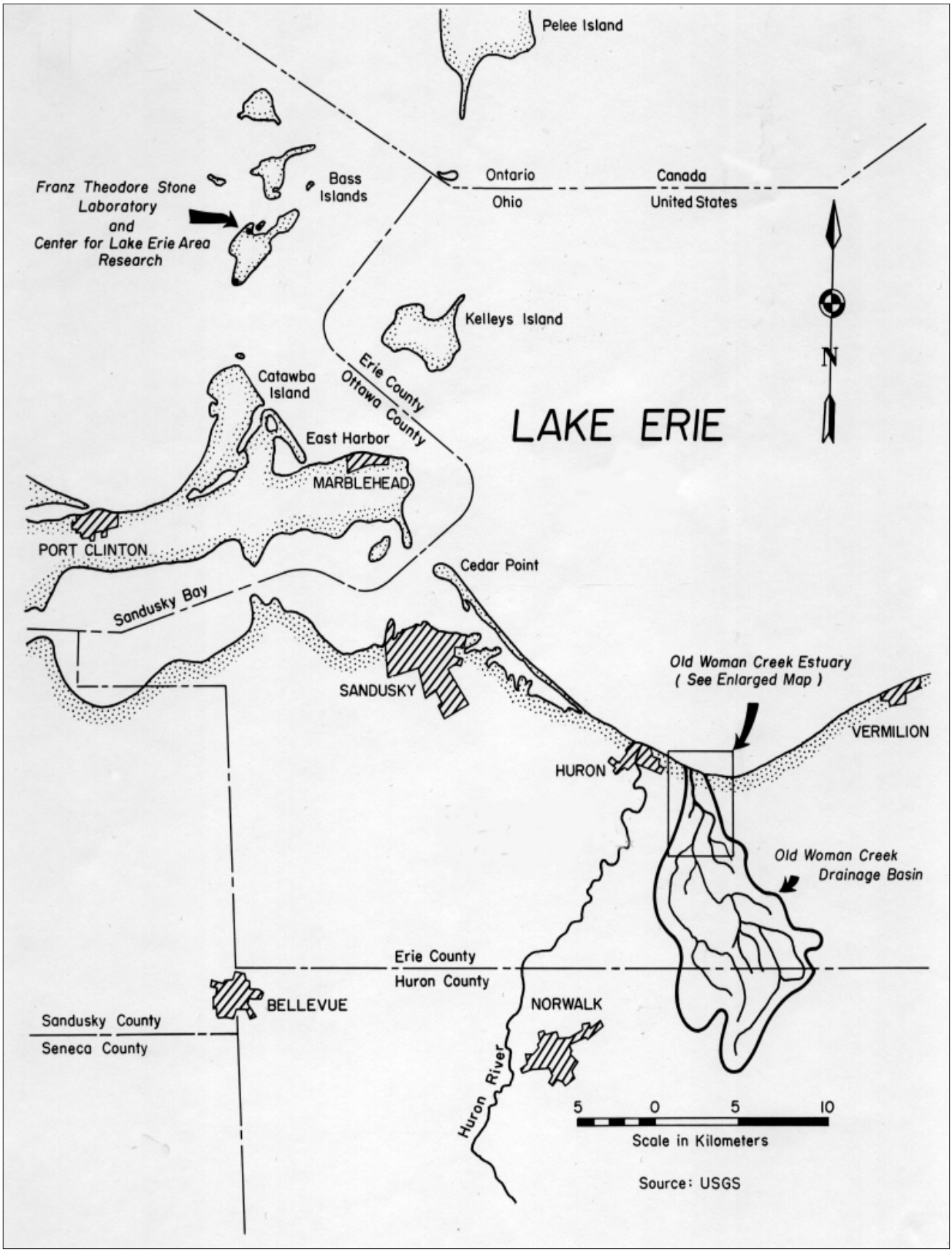

Figure 1.1. Location map of Old Woman Creek estuary and watershed.

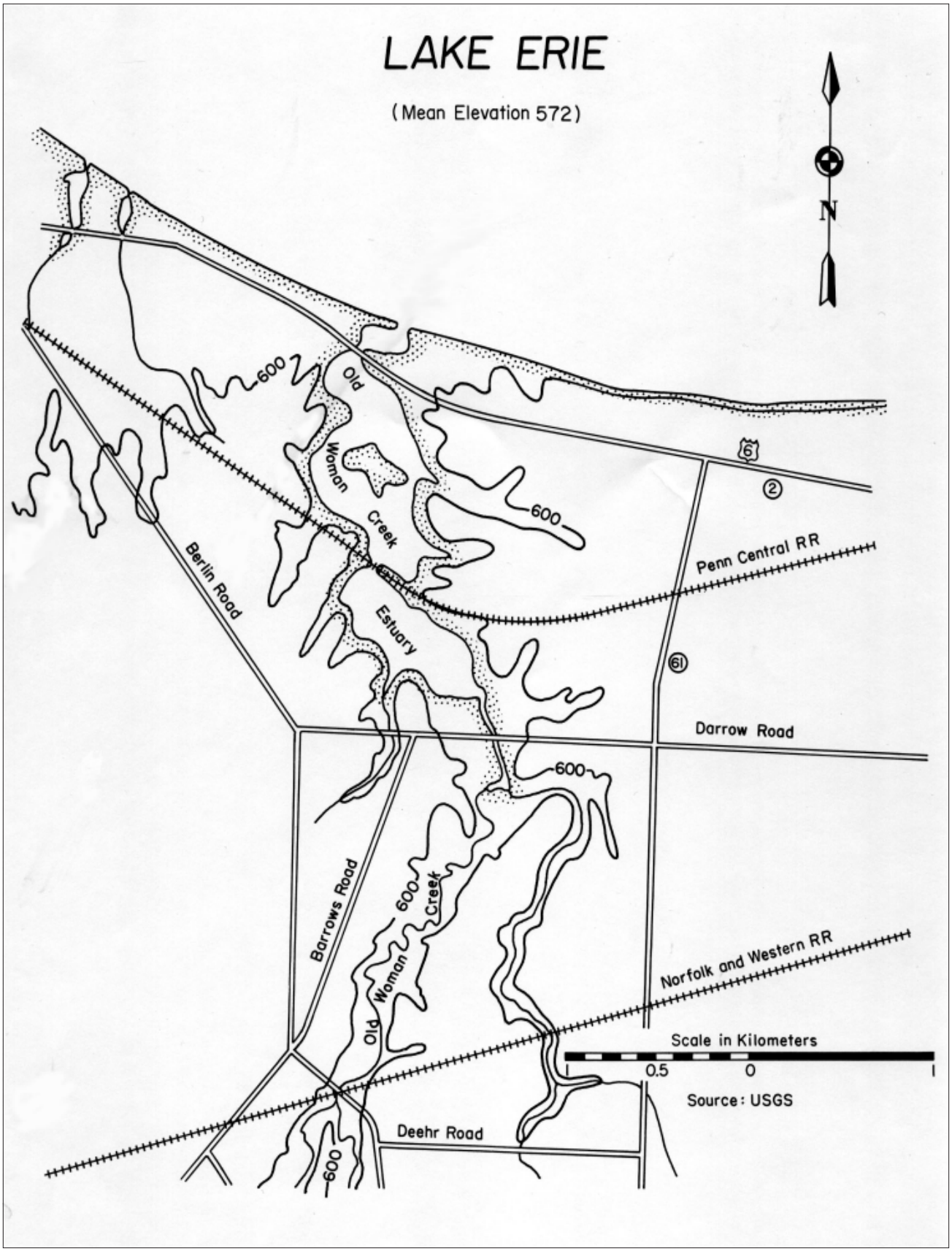

Figure 1.2. Lower reach of Old Woman Creek and its estuary in 1975. Elevations in feet above mean sea level.

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

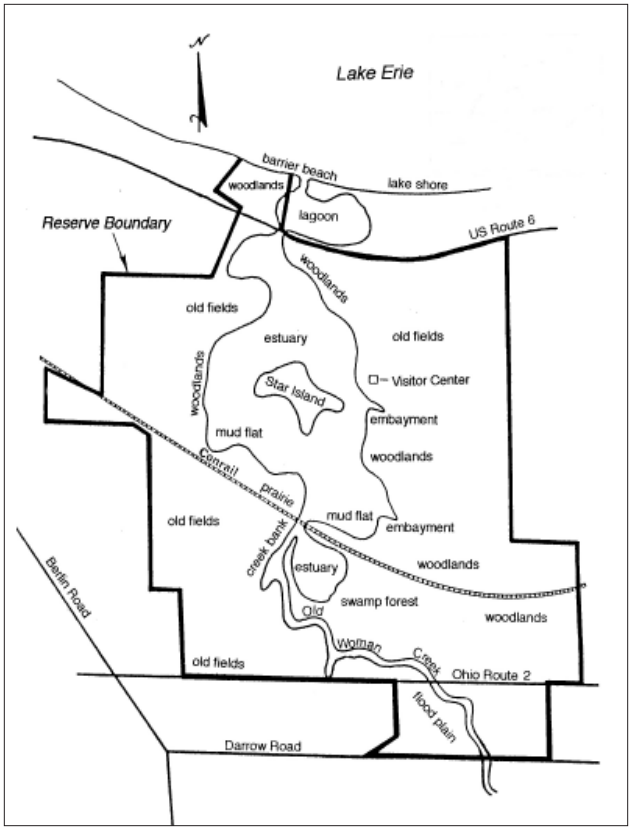

Figure 1.4. Old Woman Creek National Estuarine Research Reserve showing habitats.

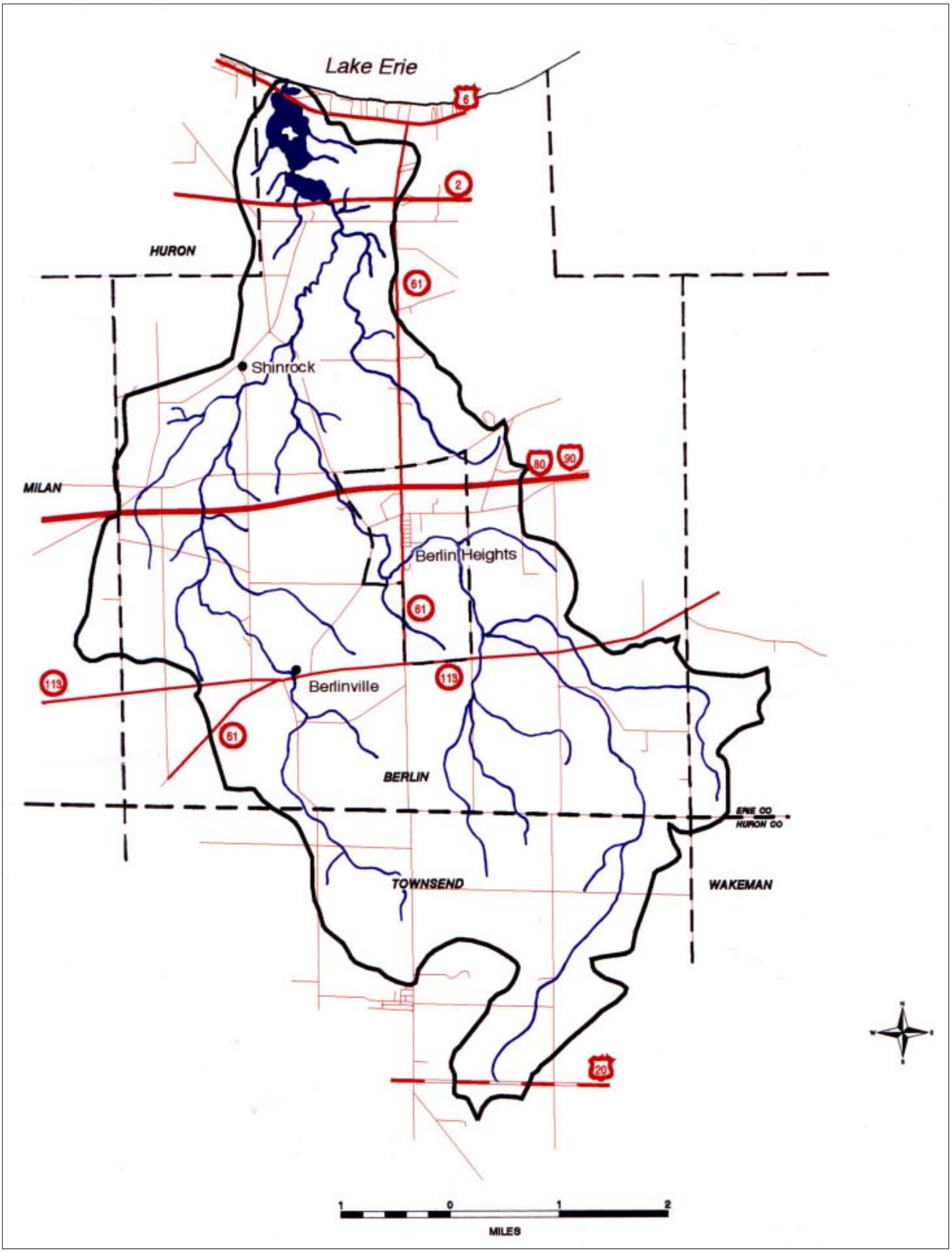

Figure 1.5. Old Woman Creek watershed.

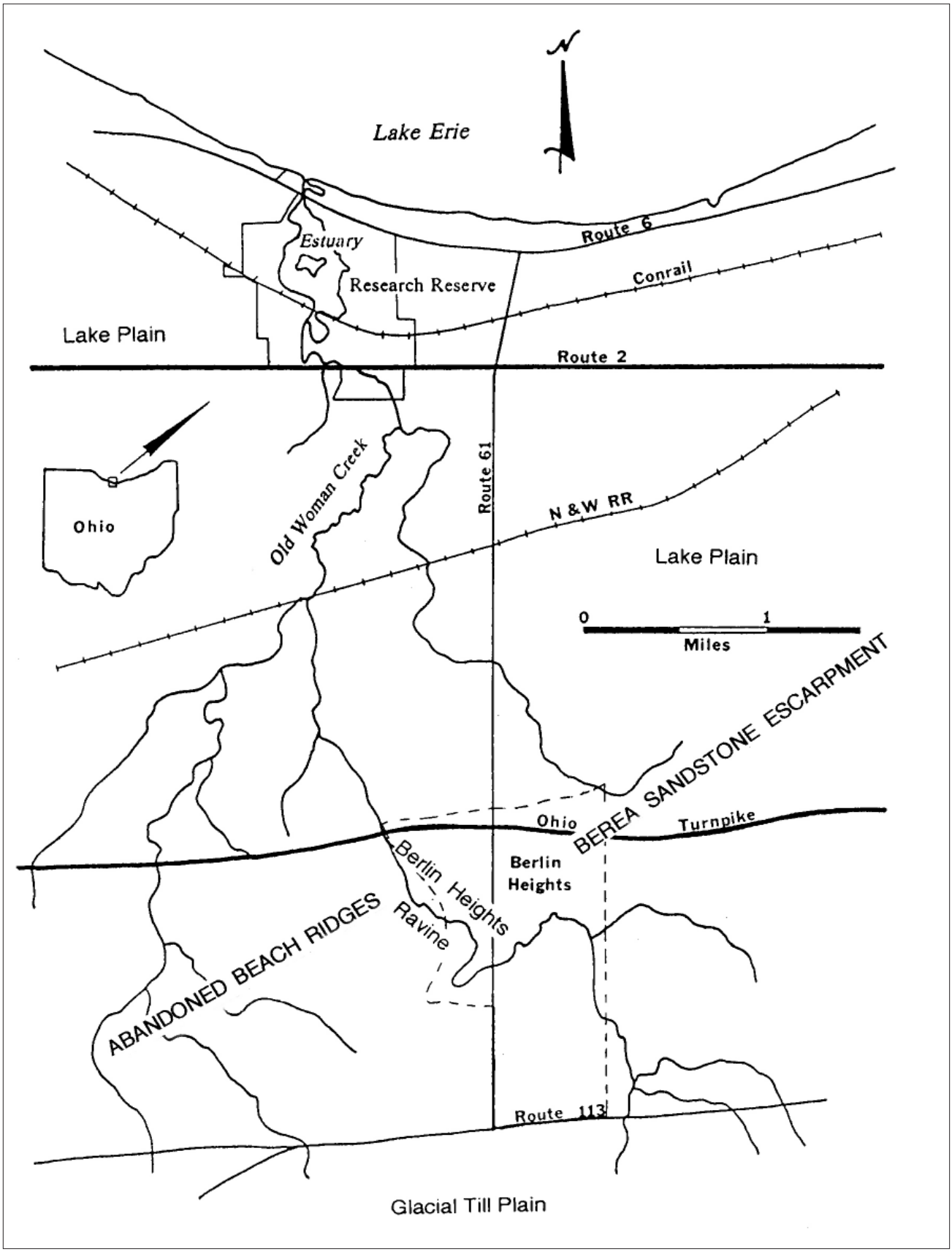

Figure 1.6. Northern portion of Old Woman Creek watershed showing tributary pattern and geomorphic features.

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).

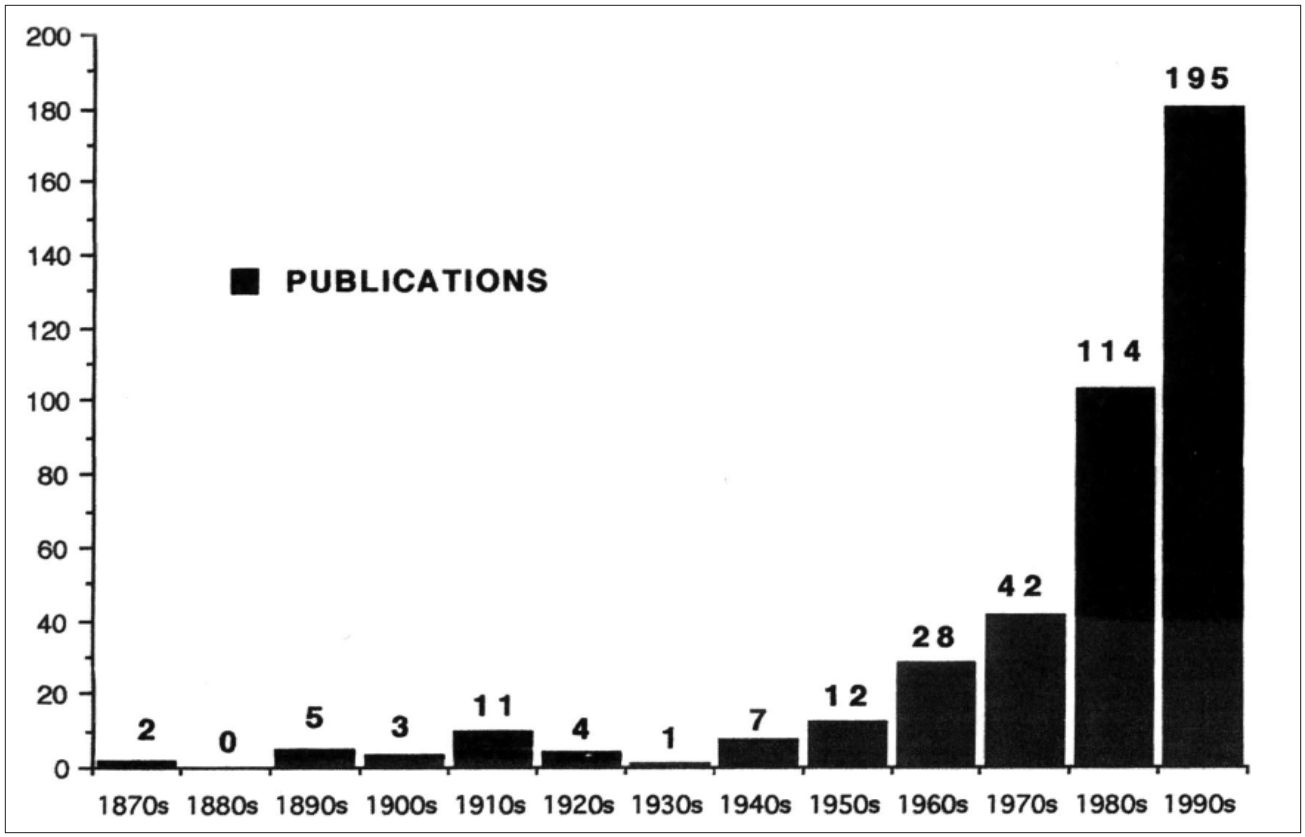

Figure 1.10. Number of publications resulting from research conducted in the vicinity of Old Woman Creek.

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

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

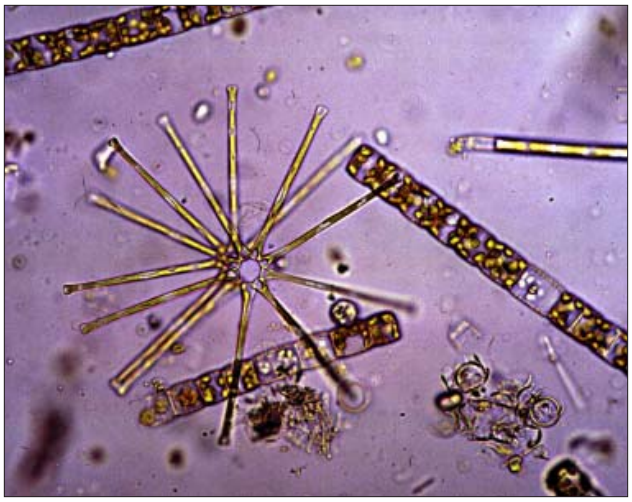

Figure 1.12. Photomicrograph of plankton from Old Woman Creek estuary (David M. Klarer).

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.

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).