

Summary of Beach Nourishment Activity Along the Great Lakes' Shoreline 1955-1996

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ABSTRACT

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This paper presents data collected by The Program for the Study of Developed Shorelines in a 1996 survey of the United States Great Lakes' beach nourishment experience. Since 1955, at least 416 individual nourishment episodes have taken place at 60 sites. A cumulative volume of at least 25 million cubic yards of sand has been placed on Great Lakes' beaches and nearshore areas. Federally funded nourishment projects dominate in the region, with three very different types of nourishment projects: mitigation, navigation and storm erosion control.

ADDITIONAL INDEX WORDS: *Replenishment, location, funding, volume, cost, length, nourishment.*

INTRODUCTION

Along U.S. coastlines many municipalities, state and federal agencies have sought to remediate beach and waterfront erosion through the process of beach nourishment. The nourishment approach is often taken as a beneficial "soft" shore stabilization method which provides and maintains desirable recreational beaches. While a few beach nourishment projects have been well recorded and monitored, most projects have not been adequately documented. Hence, in the United States, beach nourishment has not been critically assessed in terms of how it is currently conducted and how it will be conducted in the future.

To our knowledge, there have been only five attempts at making a comprehensive catalog of beach nourishment projects: The Institute of Water Resources Shoreline Protection and Beach Erosion Control Study of 1993 "the Purple Report" (USACE, 1993) which was limited to federally funded projects, a 1986 survey of the United States East Coast nourishment experience (PILKEY and CLAYTON, 1989), a 1987 survey of the Pacific Coast nourishment experience (CLAYTON, 1989) a 1989 survey of nourishment projects along the Gulf of Mexico Coast (DIXON and PILKEY, 1991) and a 1994 survey of the Pacific Coast (WIEGEL, 1994). As such, little information has been readily available on the scope and scale of the use of beach nourishment in the Great Lakes region. This paper presents the first known compilation of data from Great Lakes nourishment projects.

METHODS

This survey began with a comprehensive literature search of coastal engineering journals and conference proceedings in

order to obtain background information and identify nourishment projects. The next step in the survey was conducted by searching the libraries and files of the U.S. Army Corps of Engineers North-Central Division, and the district offices in Detroit, Chicago, and Buffalo for information on beach nourishment projects undertaken by the USACE. Additional information was obtained through state departments of natural resources and geologic surveys, local municipalities, local libraries, interviews with local residents and by on site inspection of projects.

For the purposes of this study we defined a nourishment *episode* as a single event which mechanically deposited sand on the beach or nearshore. We defined a nourishment *project* as a location where a number of episodes have occurred over time. For each nourishment episode, we attempted to obtain the following information: project location, year, funding source, volume, cost, and length.

Information on Great Lakes' beach nourishment projects varies greatly. For most older projects (before 1980) little data is available outside of the volume of sand placed and some cost figures. However, for most USACE Section 111 (mitigation) projects, the data is complete because a monitoring program is included as part of each project. The St. Joseph, Michigan mitigation project is particularly well documented (ROELLIG, 1989, USACE DETROIT DISTRICT 1996, IJC, 1990, PARSON *et al.*, 1996, USACE CONTRACT DREDGING, 1996, PARSON, 1992). Data on federal storm and erosion control projects are also generally complete. When the beach nourishment project is created from dredge spoil from a navigation project, very little data outside the volume and cost is available. Data availability on local and state projects varies, but as a general rule of thumb, the smaller the municipality and project, the less information is available. In fact,

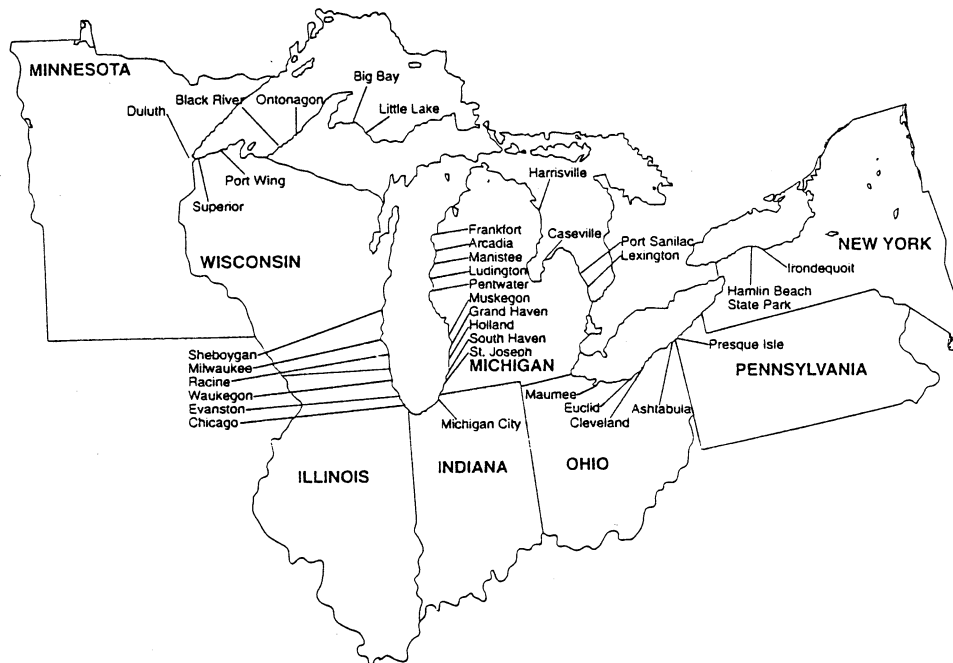


Figure 1. Index Map showing the approximate location of 35 nourishment projects (for a complete listing of projects see Table 1).

sometimes the only information available is the local knowledge that the beach had once been nourished!

In general, the information collected for the 60 known Great Lakes nourishment sites is quite good (see Figure 1 for the location of a number of selected projects). Of 416 nourishment episodes identified in the region, approximate dates are known for all but two, volume data is known for 394 episodes (95%), cost data for 268 episodes (64%), and length data for 208 episodes (50%).

PROJECT FUNDING CATEGORIES

In Table 1 and Figure 1 the broad range of project funding categories is illustrated. For purposes of categorization, the dominant funding source was chosen when multiple sources existed. Eight basic funding types were established to characterize the Great Lakes' nourishment experience. These were:

(1) Federal Storm and Erosion—A project funded in the majority by the federal government for the purpose of mitigating erosion and/or preventing future damage that is likely to occur in storm events.

(2) Federal Mitigation (111)—A project which the federal government has undertaken in an attempt to mitigate the effects of erosion attributed to federally funded and maintained, navigation structures. In the Great Lakes these projects are funded under Section 111 of the Rivers and Harbors Act of 1968.

(3) Federal Navigation—A nourishment project that is the result of a project funded for navigational purposes, which involves beach disposal of dredging spoil.

(4) Federal Unspecified—A nourishment project that is

known to be federally funded, but the specific reason for funding is unknown or unavailable.

(5) State—A project where the major source of funding is a state agency.

(6) Local—A project where the major source of funding is a county, local city, or municipality.

(7) Private—A nourishment project where the major source of funding is a private citizen or group of private citizens (such as a home owners group).

(8) Unknown—The source of funding for the project is not known.

The record for beach nourishment projects is presented in Table 1 in geographical order for each Lake. Except where noted, the costs given in Table 1 are in project year dollars (not corrected for inflation). Volume is the total cubic yards of sand placed for the given project. It may include sand from more than one pumping or source, and/or more than one disposal location. Length is the total linear (along shore) length of a project in feet.

FINDINGS

The Great Lakes beach nourishment experience differs from other regions of the U.S. in several notable ways. First, the scales of the region's nourishment projects are dramatically reduced as compared to those of the East or Gulf coast projects. Of episodes whose nourishment volume is known, 81% are smaller than 100,000 cubic yards, and another 13% are between 100,000 and 500,000 cubic yards. The total volume of nourishment sand emplaced along Great Lakes shorelines over time is an order of magnitude smaller than the

Table 1. Great Lakes Beach Nourishment Episodes (1950-1996).

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----------|-----------------------------------|-----------|-----------------------------------|-----------------------|------------------|--------------|----------------|
| Lake Erie | | | | | | | |
| 1 | Bolles Hbr, MI | 1987 | Federal: Navigation | 26,500 | 2,000 | \$128,971 | 48 |
| 2 | Bolles Hbr, MI | 1988 | Federal: Navigation | 13,837 | 2,000 | \$164,941 | 19, 48, 47 |
| 3 | Maumee Bay State Park, Oregon, OH | 1990-1991 | Federal: Storm and Erosion | 143,000 | 5,200 | \$1,517,000 | 42, 50, 41 |
| 4 | West Harbor, OH | 1987 | Unknown | 44,563 | | \$315,838 | 19 |
| 5 | West Harbor, OH | 1988 | Unknown | 74,939 | | \$439,450 | 19 |
| 6 | Century Park, Lorain, OH | 1991 | Federal: Storm and Erosion | 5,100 | 400 | \$341,300 | 42, 39 |
| 7 | Lakeview Park, Lorain, OH | 1977 | Federal: Storm and Erosion | 124,500 | 1,500 | \$833,500 | 42, 43 |
| 8 | Lakeview Park, Lorain, OH | 1980 | Federal: Storm and Erosion | 6,000 | 1,500 | \$51,000 | 42 |
| 9 | Lakeview Park, Lorain, OH | 1981 | Federal: Storm and Erosion | 3,000 | 1,500 | \$25,600 | 42 |
| 10 | Lakeview Park, Lorain, OH | 1988 | Local/Private | 100 | 1,500 | \$900 | 42 |
| 11 | Sims Park, Euclid, OH | 1992 | Federal: Storm and Erosion | 26,700 | 800 | \$512,000 | 42 |
| 12 | Sims Park, Euclid, OH | 1994 | Local/Private | 1,700 | 800 | \$18,600 | 42, 13 |
| 13 | Cleveland, OH | 1985 | Unknown | 24,550 | | \$214,905 | 19 |
| 14 | Cleveland, OH | 1987 | Unknown | 34,375 | | \$171,884 | 19 |
| 15 | Cleveland, OH | 1988 | Unknown | 16,917 | | \$103,213 | 19 |
| 16 | Cleveland, OH | 1989 | Unknown | 50,602 | | \$278,166 | 19 |
| 17 | Lakeshore Park, Ashtabula, OH | 1982-1983 | Federal: Storm and Erosion | 34,500 | 800 | \$1,666,800 | 38, 42 |
| 18 | Lakeshore Park, Ashtabula, OH | 1984 | Federal: Storm and Erosion | 4,700 | 800 | \$34,000 | 38, 42 |
| 19 | Lakeshore Park, Ashtabula, OH | 1986 | Federal: Storm and Erosion | 3,300 | 800 | \$37,000 | 38, 42 |
| 20 | Lakeshore Park, Ashtabula, OH | 1987 | Federal: Storm and Erosion | 2,700 | 800 | \$37,000 | 38, 42 |
| 21 | Lakeshore Park, Ashtabula, OH | 1988 | Federal: Storm and Erosion | ? | 800 | \$22,200 | 38, 42 |
| 22 | Lakeshore Park, Ashtabula, OH | 1989 | Federal: Storm and Erosion | 5,700 | 800 | \$49,400 | 38, 42 |
| 23 | Lakeshore Park, Ashtabula, OH | 1991 | Federal: Storm and Erosion | 5,800 | 800 | \$27,300 | 38, 42 |
| 24 | Lakeshore Park, Ashtabula, OH | 1992 | Local/Private | 270 | 800 | | 38, 42 |
| 25 | Lakeshore Park, Ashtabula, OH | 1993 | Local/Private | 400 | 800 | | 38, 42 |
| 26 | Lakeshore Park, Ashtabula, OH | 1996 | Local/Private | 1,500-2,000 | 800 | | 8 |
| 27 | Presque Isle State Park, Erie, PA | 1955-1956 | Federal: Storm and Erosion | 4,150,000 | | \$2,451,000 | 42 |
| 28 | Presque Isle State Park, Erie, PA | 1960-1961 | Federal: Storm and Erosion | 681,500 | | \$500,000 | 16 |
| 29 | Presque Isle State Park, Erie, PA | 1964-1965 | Federal: Storm and Erosion | 402,300 | | \$355,000 | 16, 3 |
| 30 | Presque Isle State Park, Erie, PA | 1965-1966 | Federal: Storm and Erosion | 30,000 | | \$166,000 | 16 |
| 31 | Presque Isle State Park, Erie, PA | 1968-1969 | Federal: Storm and Erosion | 68,467 | | \$348,000 | 16 |
| 32 | Presque Isle State Park, Erie, PA | 1971 | Federal: Storm and Erosion | 101,667 | | | 16 |
| 33 | Presque Isle State Park, Erie, PA | 1973 | Federal Emergency Erosion Control | 66,667 | | \$240,000 | 16 |
| 34 | Presque Isle State Park, Erie, PA | 1975 | Federal: Storm and Erosion | 124,667 | | \$1,097,000 | 16 |
| 35 | Presque Isle State Park, Erie, PA | 1976 | Federal: Storm and Erosion | 122,000 | | \$1,109,500 | 16 |
| 36 | Presque Isle State Park, Erie, PA | 1977 | Federal: Storm and Erosion | 191,333 | | \$1,077,000 | 16 |
| 37 | Presque Isle State Park, Erie, PA | 1978 | Federal: Storm and Erosion | 115,333 | | \$1,073,400 | 16 |
| 38 | Presque Isle State Park, Erie, PA | 1979 | Federal: Storm and Erosion | 144,000 | | \$1,060,500 | 16 |
| 39 | Presque Isle State Park, Erie, PA | 1980 | Federal: Storm and Erosion | 144,000 | | \$1,082,100 | 16 |
| 40 | Presque Isle State Park, Erie, PA | 1981 | Federal: Storm and Erosion | 157,333 | | \$1,213,300 | 16 |
| 41 | Presque Isle State Park, Erie, PA | 1982 | Federal: Storm and Erosion | 189,333 | | \$1,424,400 | 16 |
| 42 | Presque Isle State Park, Erie, PA | 1983 | Federal: Storm and Erosion | 129,333 | | \$1,049,000 | 16, 26 |
| 43 | Presque Isle State Park, Erie, PA | 1984-1985 | Federal: Storm and Erosion | 336,667 | | \$3,007,000 | 16, 26 |
| 44 | Presque Isle State Park, Erie, PA | 1986 | Federal: Storm and Erosion | 172,000 | | \$1,631,400 | 16, 26 |
| 45 | Presque Isle State Park, Erie, PA | 1987 | Federal: Storm and Erosion | 228,000 | | \$1,675,000 | 16, 26 |
| 46 | Presque Isle State Park, Erie, PA | 1988 | Federal: Storm and Erosion | 158,667 | | \$1,529,200 | 16, 26 |
| 47 | Presque Isle State Park, Erie, PA | 1989 | Federal: Storm and Erosion | 179,333 | | \$1,599,900 | 16, 26 |
| 48 | Presque Isle State Park, Erie, PA | 1990 | Federal: Storm and Erosion | 113,333 | | \$993,200 | 16, 26 |
| 49 | Presque Isle State Park, Erie, PA | 1991 | Federal: Storm and Erosion | 207,380 | | \$1,206,900 | 16, 26 |
| 50 | Presque Isle State Park, Erie, PA | 1992 | Federal: Storm and Erosion | 415,000 | 29,040 | \$4,379,000 | 42, 25, 40, 26 |

Table 1. Continued.

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|---------------|-------------------------------------|-----------|----------------------------|-----------------------|------------------|--------------|------------|
| 51 | Presque Isle State Park, Erie, PA | 1993 | Federal: Storm and Erosion | 31,913 | 29,040 | \$675,000 | 26 |
| 52 | Presque Isle State Park, Erie, PA | 1994 | Federal: Storm and Erosion | 35,379 | 29,040 | \$789,840 | 42, 6 |
| 53 | Presque Isle State Park, Erie, PA | 1995 | Federal: Storm and Erosion | 33,957 | 29,040 | \$854,075 | 26 |
| 54 | Presque Isle State Park, Erie, PA | 1996 | Federal: Storm and Erosion | 34,071 | 29,040 | | 26 |
| Lake Huron | | | | | | | |
| 55 | Hammond Bay, MI | 1992 | Federal: Unknown | 3,390 | 450 | | 48 |
| 56 | Au Sable, MI | 1991 | Federal: Navigation | 40,605 | 3,000 | \$132,834 | 48, 47 |
| 57 | Harrisville, MI | 1983 | Federal: Navigation | 23,300 | | | 47 |
| 58 | Harrisville, MI | 1984 | Federal: Mitigation | 64,665 | 1,200 | | 48 |
| 59 | Harrisville, MI | 1987 | Federal: Mitigation | 45,770 | 2,500 | \$181,465 | 19, 47, 48 |
| 60 | Harrisville, MI | 1993 | Federal: Mitigation | 13,578 | 2,500 | \$114,267 | 47, 48 |
| 61 | Tawas Bay, MI | 1974 | State/Local | 3,000 | 400 | \$6,000 | 5 |
| 62 | Tawas Bay, MI | 1973-1974 | State/Local | 4,250 | 400 | \$8,000 | 5 |
| 63 | Caseville Hbr, MI | 1995 | Federal: Navigation | 17,655 | | \$189,298 | 47, 48 |
| 64 | Port Sanilac, MI | 1977 | Federal: Mitigation | 91,667 | 4,700 | | 48 |
| 65 | Port Sanilac, MI | 1982 | Federal: Mitigation | 28,167 | 4,700 | | 48 |
| 66 | Port Sanilac, MI | 1984 | Federal: Mitigation | 35,679 | 4,700 | | 48 |
| 67 | Port Sanilac, MI | 1985 | Federal: Mitigation | 34,167 | 4,700 | \$174,660 | 48 |
| 68 | Port Sanilac, MI | 1988 | Federal: Mitigation | 34,556 | 4,700 | \$233,041 | 19, 47, 48 |
| 69 | Port Sanilac, MI | 1991 | Federal: Mitigation | 10,571 | 4,700 | \$75,021 | 47, 48 |
| 70 | Port Sanilac, MI | 1996 | Federal: Mitigation | | | | 47 |
| 71 | Lexington, MI | 1980 | Federal: Mitigation | 25,153 | | | 48 |
| 72 | Lexington, MI | 1980 | Federal: Mitigation | 47,917 | | | 48 |
| 73 | Lexington, MI | 1982 | Federal: Mitigation | 40,000 | 4,200 | | 48 |
| 74 | Lexington, MI | 1985 | Federal: Mitigation | 40,000 | 3,600 | \$204,480 | 48 |
| 75 | Lexington, MI | 1986 | Federal: Mitigation | 33,333 | 3,000 | \$198,000 | 48 |
| 76 | Lexington, MI | 1987 | Federal: Mitigation | | | | 47 |
| 77 | Lexington, MI | 1988 | Federal: Mitigation | 49,036 | 3,000 | \$347,173 | 48 |
| 78 | Lexington, MI | 1991 | Federal: Mitigation | 20,350 | 3,100 | \$93,112 | 47, 48 |
| 79 | Lexington, MI | 1994 | Federal: Mitigation | 79,000 | 3,475 | \$ 418,700 | 48 |
| 80 | Lexington, MI | 1996 | Federal: Mitigation | | | | 48, 23 |
| Lake Michigan | | | | | | | |
| 81 | Kewaunee, WI | 1992 | Federal: Unknown | 37,500 | | | 48 |
| 82 | Two Rivers, WI | 1989 | Federal: Navigation | 49,633 | 1,300 | \$229,860 | 19, 47, 48 |
| 83 | Sheboygan, WI | 1985 | Federal: Navigation | 12,026 | 2,550 | \$94,060 | 19, 47, 48 |
| 84 | Sheboygan, WI | 1987 | Federal: Navigation | 24,303 | 3,050 | \$175,968 | 19, 47, 48 |
| 85 | Sheboygan, WI | 1991 | Federal: Navigation | 46,557 | 700 | \$219,586 | 47, 48 |
| 86 | Milwaukee, WI | | Local/Private | | 833 | | 24, 17 |
| 87 | Milwaukee Co., WI | | Local/Private | | 219 | | 24, 17 |
| 88 | Racine, WI | 1985 | Federal: Unknown | 1,246 | | | 48 |
| 89 | Racine, WI | 1986 | Federal: Unknown | 2,000 | | | 48 |
| 90 | Illinois Beach State Park, Zion, IL | 1984 | State/Local | 90,000 | 1,000 | \$35,000 | 20 |
| 91 | Illinois Beach State Park, Zion, IL | 1985-1995 | State/Local | 202,000 | | | 28 |
| 92 | Illinois Beach State Park, Zion, IL | 1995 | State/Local | 44,000 | | | 28 |
| 93 | Waukegan, IL | 1984-1985 | Federal: Unknown | 81,000 | | | 7 |
| 94 | Waukegan, IL | 1985 | Federal: Unknown | 26,180 | | \$139,915 | 19, 7 |
| 95 | Waukegan, IL | 1988 | Federal: Unknown | 100,996 | | \$525,110 | 19, 47, 7 |
| 96 | Waukegan, IL | 1990 | Federal: Unknown | 49,513 | | | 7 |

Table 1. Continued.

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|------------------------------|-----------|----------------------------|-----------------------|------------------|--------------|------------|
| 97 | Waukegan, IL | 1991 | Federal: Unknown | 79,482 | | | 7 |
| 98 | Waukegan, IL | 1993 | Federal: Unknown | 66,597 | | | 7 |
| 99 | Waukegan, IL | 1994 | Federal: Unknown | 44,879 | | | 7 |
| 100 | Lake Forest, IL | 1986-1987 | Local/Private | 125,000 | | \$9,000,000 | 24, 1, 7 |
| 101 | Evanston, IL | 1970 | Federal: Storm and Erosion | | | \$801,802 | 32 |
| 102 | Evanston, IL | 1979 | Federal: Storm and Erosion | | | \$568,127 | 32, 33 |
| 103 | Evanston, IL | 1986 | Local/Private | 2,000 | | | 14 |
| 104 | Evanston, IL | 1987 | Local/Private | 5,000 | | | 14 |
| 105 | Evanston, IL | 1988 | Local/Private | 5,500 | | | 14 |
| 106 | Evanston, IL | 1991 | Local/Private | 7,260 | | | 14 |
| 107 | Evanston, IL | 1994 | Local/Private | 7,120 | | | 14 |
| 108 | Evanston, IL | 1995 | Local/Private | 8,040 | | | 14 |
| 109 | Evanston, IL | 1996 | Local/Private | 8,000 | | | 14 |
| 110 | Chicago | 1961 | Unknown | 193,000 | | | 4 |
| 111 | Chicago | 1962 | Federal: Unknown | 400,000 | | | 4 |
| 112 | Chicago | 1964 | Local/Private | 5,300 | | | 4 |
| 113 | Chicago | 1987 | Unknown | 13,140 | | | 4 |
| 114 | Burns SB Hbr | 1985 | Federal: Navigation | 126,000 | | \$377,025 | 19, 46 |
| 115 | Burns SB Hbr | 1986 | Federal: Navigation | 5,000 | | | 46 |
| 116 | Burns SB Hbr | 1986 | Federal: Navigation | 4,000 | | | 46 |
| 117 | Burns SB Hbr | 1987 | Federal: Navigation | 126,400 | | | 46 |
| 118 | Ogden Dunes, IN | 1986 | Federal: Navigation | 125,000 | | | 46 |
| 119 | Ogden Dunes, IN | 1989 | Local/Private | 211,000 | | | 46 |
| 120 | Ogden Dunes, IN | 1992 | Local/Private | 134,500 | | | 46 |
| 121 | Mt. Baldy, Michigan City, IN | 1974 | Federal: Storm and Erosion | 226,000 | | | 45 |
| 122 | Mt. Baldy, Michigan City, IN | 1982 | Federal: Storm and Erosion | 80,000 | 3,065 | \$1,500,000 | 45, 35 |
| 123 | Mt. Baldy, Michigan City, IN | 1996 | Federal: Storm and Erosion | 35,000 | 10,600 | | 12, 44 |
| 124 | Mt. Baldy, Michigan City, IN | 1996 | Federal: Storm and Erosion | 60,000 | 10,600 | | 12, 44 |
| 125 | Michigan City, IN | 1986 | Federal: Navigation | 68,044 | | | 19 |
| 126 | Michigan City, IN | 1990 | Federal: Navigation | 3,000 | | | 47 |
| 127 | New Buffalo, MI | 1974 | Federal: Navigation | 250,000 | | | 30, 21 |
| 128 | New Buffalo, MI | 1979 | Federal: Unknown | 6,100 | | | 48 |
| 129 | New Buffalo, MI | 1980 | Federal: Unknown | 163,333 | 1,000 | | 48 |
| 130 | New Buffalo, MI | 1980 | Federal: Unknown | 15,700 | | | 48 |
| 131 | New Buffalo, MI | 1980-1981 | Federal: Unknown | ? | | | 48, 30, 21 |
| 132 | New Buffalo, MI | 1983 | Federal: Navigation | 22,628 | 1,500 | \$76,015 | 47, 48 |
| 133 | New Buffalo, MI | 1985 | Federal: Unknown | 130,658 | 1,300 | \$682,187 | 48 |
| 134 | New Buffalo, MI | 1985 | Federal: Navigation | 9,795 | 200 | \$60,990 | 19, 47, 48 |
| 135 | New Buffalo, MI | 1988 | Federal: Navigation | 10,136 | 1,500 | \$83,194 | 19, 47, 48 |
| 136 | New Buffalo, MI | 1988 | Federal: Unknown | 31,492 | 1,500 | \$125,300 | 47 |
| 137 | New Buffalo, MI | 1990 | Federal: Navigation | 14,920 | 1,500 | \$71,760 | 47, 48 |
| 138 | New Buffalo, MI | 1991 | Federal: Unknown | 53,538 | 1,500 | \$271,404 | 47 |
| 139 | New Buffalo, MI | 1992 | Federal: Navigation | 11,931 | 1,500 | \$73,203 | 47, 48 |
| 140 | New Buffalo, MI | 1994 | Federal: Navigation | 60,401 | 1,500 | \$283,335 | 47, 48 |
| 141 | New Buffalo, MI | 1995 | Federal: Unknown | 95,000 | 1,500 | \$95,000 | 48 |
| 142 | Saint Joseph, MI | 1971 | Federal: Unknown | 21,275 | | | 48, 28 |
| 143 | Saint Joseph, MI | 1972 | Federal: Unknown | 43,060 | | | 48, 28 |
| 144 | Saint Joseph, MI | 1973 | Federal: Unknown | 7,966 | | | 48, 28 |
| 145 | Saint Joseph, MI | 1974 | Federal: Unknown | 25,624 | | | 48, 28 |

Table 1. *Continued.*

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|------------------|-----------|---------------------|--------------------|----------------|-----------|--------------------|
| 146 | Saint Joseph, MI | 1975 | Federal: Unknown | 50,815 | | | 48, 28 |
| 147 | Saint Joseph, MI | 1976 | Federal: Mitigation | 278,000 | | | 48, 30, 53, 51 |
| 148 | Saint Joseph, MI | 1976 | Federal: Mitigation | 94,185 | | | 48, 28, 22 |
| 149 | Saint Joseph, MI | 1977 | Federal: Mitigation | 161,996 | | | 48, 28 |
| 150 | Saint Joseph, MI | 1978 | Federal: Mitigation | 89,493 | | | 48, 28 |
| 151 | Saint Joseph, MI | 1979 | Federal: Mitigation | 110,835 | | | 48, 28 |
| 152 | Saint Joseph, MI | 1980 | Federal: Mitigation | 92,990 | | | 18, 48, 28 |
| 153 | Saint Joseph, MI | 1980-1981 | Federal: Mitigation | 65,826 | | \$262,083 | 18, 48, 28 |
| 154 | Saint Joseph, MI | 1982 | Federal: Mitigation | 117,589 | | | 48, 28 |
| 155 | Saint Joseph, MI | 1983 | Federal: Mitigation | 221,513 | | | 48, 28 |
| 156 | Saint Joseph, MI | 1984 | Federal: Mitigation | 100,000 | 18, 48, 47, 28 | | |
| 157 | Saint Joseph, MI | 1985 | Federal: Mitigation | 37,701 | 3,400 | \$209,404 | 19, 48, 47, 30, 28 |
| 158 | Saint Joseph, MI | 1986 | Federal: Mitigation | 14,533 | 3,400 | \$101,004 | 19, 48, 47, 28 |
| 159 | Saint Joseph, MI | 1986 | Federal: Mitigation | 172,033 | 3,400 | \$529,801 | 48, 28 |
| 160 | Saint Joseph, MI | 1987 | Federal: Mitigation | 3,320 | 1,000 | \$36,636 | 48, 28 |
| 161 | Saint Joseph, MI | 1987 | Federal: Mitigation | 67,500 | 2,400 | \$280,260 | 48, 28 |
| 162 | Saint Joseph, MI | 1988 | Federal: Mitigation | 43,725 | | \$291,446 | 19, 48, 47 |
| 163 | Saint Joseph, MI | 1988 | Federal: Mitigation | 67,500 | 2,000 | \$255,150 | 48, 28 |
| 164 | Saint Joseph, MI | 1989 | Federal: Mitigation | 18,745 | 2,700 | \$147,425 | 19, 48, 47, 28 |
| 165 | Saint Joseph, MI | 1990 | Federal: Mitigation | 58,314 | 2,700 | \$317,066 | 48, 47, 28 |
| 166 | Saint Joseph, MI | 1991 | Federal: Mitigation | 52,513 | | \$278,153 | 48, 47, 28 |
| 167 | Saint Joseph, MI | 1991 | Federal: Mitigation | 83,383 | 2,800 | \$424,505 | 48, 27 |
| 168 | Saint Joseph, MI | 1992 | Federal: Mitigation | 33,644 | 2,700 | \$123,333 | 48, 47, 28 |
| 169 | Saint Joseph, MI | 1993 | Federal: Mitigation | 2,360 | 2,700 | \$13,185 | 48, 47, 28 |
| 170 | Saint Joseph, MI | 1993 | Federal: Mitigation | 60,025 | 1,300 | \$284,522 | 48, 28, 10 |
| 171 | Saint Joseph, MI | 1994 | Federal: Mitigation | 31,469 | | \$439,744 | 48, 47, 10, 11 |
| 172 | Saint Joseph, MI | 1995 | Federal: Mitigation | 33,335 | 2,500 | \$185,007 | 48, 47 |
| 173 | Saint Joseph, MI | 1995 | Federal: Mitigation | 63,355 | 1,300 | \$308,186 | 48 |
| 174 | Saint Joseph, MI | 1996 | Federal: Mitigation | | | | 47 |
| 175 | South Haven, MI | 1971 | Federal: Unknown | 4,844 | | | 48 |
| 176 | South Haven, MI | 1972 | Federal: Unknown | 16,196 | | | 48 |
| 177 | South Haven, MI | 1973 | Federal: Unknown | 39,379 | | | 48 |
| 178 | South Haven, MI | 1974 | Federal: Unknown | 17,219 | | | 48 |
| 179 | South Haven, MI | 1975 | Federal: Unknown | 9,787 | | | 48 |
| 180 | South Haven, MI | 1976 | Federal: Unknown | 10,716 | | | 48 |
| 181 | South Haven, MI | 1976 | Federal: Mitigation | 250,000 | 3,500 | | 48 |
| 182 | South Haven, MI | 1977 | Federal: Mitigation | 200,000 | | | 30, 52 |
| 183 | South Haven, MI | 1981 | Federal: Mitigation | 79,888 | | | 48, 30 |
| 184 | South Haven, MI | 1985 | Federal: Mitigation | 114,969 | 5,800 | \$666,900 | 48 |
| 185 | South Haven, MI | 1994 | Federal: Mitigation | 22,247 | 5,800 | \$121,684 | 48, 47 |
| 186 | South Haven, MI | 1994 | Federal: Mitigation | 60,000 | 2,200 | \$378,000 | 48 |
| 187 | Suagatuck, MI | 1985 | Federal: Navigation | 19,880 | | \$107,432 | 19, 48, 47 |
| 188 | Suagatuck, MI | 1989-1990 | Federal: Navigation | ? | 2,500 | \$50,652 | 19, 48, 47 |
| 189 | Suagatuck, MI | 1993 | Federal: Navigation | 11,461 | 2,300 | \$47,978 | 48, 47 |
| 190 | Holland, MI | 1972 | Federal: Unknown | 24,291 | | | 48 |
| 191 | Holland, MI | 1973 | Federal: Unknown | 30,659 | | | 48 |
| 192 | Holland, MI | 1974 | Federal: Unknown | 74,425 | | | 48 |
| 193 | Holland, MI | 1975 | Federal: Unknown | 84,007 | | | 48 |
| 194 | Holland, MI | 1976 | Federal: Unknown | 34,304 | | | 48 |
| 195 | Holland, MI | 1977 | Federal: Mitigation | 24,050 | | | 48 |

Table 1. Continued.

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|-----------------|-----------|---------------------|-----------------------|------------------|--------------|------------|
| 196 | Holland, MI | 1978 | Federal: Mitigation | 160,000 | | | 48 |
| 197 | Holland, MI | 1978 | Federal: Mitigation | 38,609 | | | 48 |
| 198 | Holland, MI | 1979 | Federal: Mitigation | 30,028 | | | 48 |
| 199 | Holland, MI | 1980 | Federal: Mitigation | 43,367 | 3,800 | \$72,173 | 48 |
| 200 | Holland, MI | 1981 | Federal: Mitigation | 16,624 | | | 48 |
| 201 | Holland, MI | 1982 | Federal: Mitigation | 35,104 | | | 48 |
| 202 | Holland, MI | 1983 | Federal: Mitigation | 48,634 | | | 18, 48 |
| 203 | Holland, MI | 1985 | Federal: Mitigation | 42,695 | | \$167,926 | 19, 48, 47 |
| 204 | Holland, MI | 1985 | Federal: Mitigation | 100,658 | 3,300 | \$278,937 | 19, 48, 47 |
| 205 | Holland, MI | 1986 | Federal: Mitigation | 35,099 | 1,300 | \$449,000 | 19, 48, 47 |
| 206 | Holland, MI | 1986 | Federal: Mitigation | 100,833 | 3,200 | \$261,488 | 19, 48, 47 |
| 207 | Holland, MI | 1987 | Federal: Mitigation | 19,046 | 3,300 | \$548,130 | 48 |
| 208 | Holland, MI | 1988 | Federal: Mitigation | 24,708 | 3,300 | \$139,185 | 19, 48, 47 |
| 209 | Holland, MI | 1989 | Federal: Mitigation | 16,263 | 3,300 | \$177,802 | 19, 48, 47 |
| 210 | Holland, MI | 1990 | Federal: Mitigation | 20,777 | 3,300 | \$86,970 | 19, 48, 47 |
| 211 | Holland, MI | 1991 | Federal: Mitigation | 20,738 | 3,300 | \$96,224 | 48, 47 |
| 212 | Holland, MI | 1992 | Federal: Mitigation | 28,120 | 3,300 | \$98,767 | 48, 47 |
| 213 | Holland, MI | 1993 | Federal: Mitigation | 26,732 | 1,200 | \$140,693 | 48, 47 |
| 214 | Holland, MI | 1994 | Federal: Mitigation | 17,849 | 3,300 | \$88,712 | 48, 47 |
| 215 | Holland, MI | 1995 | Federal: Mitigation | 18,367 | 1,000 | \$110,857 | 48, 47 |
| 216 | Holland, MI | 1996 | Federal: Mitigation | | | \$93,380 | 48, 47 |
| 217 | Grand Haven, MI | 1973 | Federal: Unknown | 29,391 | | | 47 |
| 218 | Grand Haven, MI | 1974 | Federal: Unknown | 42,014 | | | 48 |
| 219 | Grand Haven, MI | 1975 | Federal: Unknown | 31,429 | | | 48 |
| 220 | Grand Haven, MI | 1976 | Federal: Unknown | 38,936 | | | 48 |
| 221 | Grand Haven, MI | 1978 | Federal: Unknown | 34,436 | | | 48 |
| 222 | Grand Haven, MI | 1979 | Federal: Mitigation | 41,437 | | | 48, 49 |
| 223 | Grand Haven, MI | 1979 | Federal: Mitigation | 30,700 | | | 48, 49 |
| 224 | Grand Haven, MI | 1980 | Federal: Mitigation | 17,084 | | | 48, 49 |
| 225 | Grand Haven, MI | 1980 | Federal: Mitigation | 10,962 | | | 18, 48, 49 |
| 226 | Grand Haven, MI | 1981 | Federal: Mitigation | 13,440 | | | 48, 49 |
| 227 | Grand Haven, MI | 1982 | Federal: Mitigation | 20,280 | | \$90,324 | 48, 49 |
| 228 | Grand Haven, MI | 1983 | Federal: Mitigation | 24,720 | | | 48, 49 |
| 229 | Grand Haven, MI | 1983-1984 | Federal: Mitigation | 25,442 | | | 48, 49 |
| 230 | Grand Haven, MI | 1985 | Federal: Mitigation | 49,640 | 3,500 | \$135,479 | 18, 47, 48 |
| 231 | Grand Haven, MI | 1986 | Federal: Mitigation | 12,710 | 1,500 | \$382,258 | 19, 47, 48 |
| 232 | Grand Haven, MI | 1986 | Federal: Mitigation | 33,564 | 2,250 | \$51,860 | 48 |
| 233 | Grand Haven, MI | 1986 | Federal: Mitigation | 154,165 | 19,760 | \$318,325 | 48, 47 |
| 234 | Grand Haven, MI | 1987 | Federal: Mitigation | 22,442 | 5,300 | \$936,325 | 48 |
| 235 | Grand Haven, MI | 1988 | Federal: Mitigation | 22,636 | 1,500 | \$217,837 | 19, 48, 47 |
| 236 | Grand Haven, MI | 1989 | Federal: Mitigation | 15,359 | 1,500 | \$196,852 | 19, 48, 47 |
| 237 | Grand Haven, MI | 1990 | Federal: Mitigation | 16,221 | 1,000 | \$146,762 | 19, 48, 47 |
| 238 | Grand Haven, MI | 1991 | Federal: Mitigation | 23,300 | 1,000 | \$115,703 | 48, 47 |
| 239 | Grand Haven, MI | 1992 | Federal: Mitigation | 57,018 | 2,000 | \$207,665 | 48, 47 |
| 240 | Grand Haven, MI | 1993 | Federal: Mitigation | 19,021 | 1,500 | \$355,410 | 48, 47 |
| 241 | Grand Haven, MI | 1994 | Federal: Mitigation | 21,212 | 2,500 | \$110,675 | 48, 47 |
| 242 | Grand Haven, MI | 1995 | Federal: Mitigation | 23,858 | 1,500 | \$158,258 | 48, 47 |
| 243 | Grand Haven, MI | 1996 | Federal: Mitigation | | | \$135,612 | 48, 47 |
| 244 | Muskegon, MI | 1973 | Federal: Unknown | | | | 47 |
| 245 | Muskegon, MI | 1974 | Federal: Unknown | 8,288 | | | 48 |
| 246 | Muskegon, MI | 1975 | Federal: Unknown | 31,560 | | | 48 |
| | | | | 65,626 | | | 48 |

Table 1. *Continued.*

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|----------------|------|---------------------|-----------------------|------------------|--------------|------------|
| 247 | Muskegon, MI | 1976 | Federal: Unknown | 43,902 | | | 48 |
| 248 | Muskegon, MI | 1977 | Federal: Unknown | 48,789 | | | 48 |
| 249 | Muskegon, MI | 1978 | Federal: Mitigation | 34,817 | | | 48 |
| 250 | Muskegon, MI | 1979 | Federal: Mitigation | 36,487 | | | 48 |
| 251 | Muskegon, MI | 1980 | Federal: Mitigation | 28,636 | | | 48 |
| 252 | Muskegon, MI | 1982 | Federal: Mitigation | 58,450 | | \$166,084 | 48 |
| 253 | Muskegon, MI | 1984 | Federal: Mitigation | 50,511 | 16,700 | \$163,055 | 48, 47 |
| 254 | Muskegon, MI | 1986 | Federal: Mitigation | 325,534 | 3,000 | \$1,489,536 | 48, 2, 15 |
| 255 | Muskegon, MI | 1988 | Federal: Mitigation | 53,774 | 6,500 | \$306,931 | 19, 48, 47 |
| 256 | Muskegon, MI | 1989 | Federal: Mitigation | 75,833 | 1,800 | \$285,316 | 48 |
| 257 | Muskegon, MI | 1991 | Federal: Mitigation | 85,107 | 4,000 | \$319,089 | 48, 47 |
| 258 | Muskegon, MI | 1993 | Federal: Mitigation | 93,573 | 4,000 | \$633,280 | 48, 47 |
| 259 | Muskegon, MI | 1994 | Federal: Mitigation | 89,000 | 4,500 | \$454,230 | 48 |
| 260 | Muskegon, MI | 1996 | Federal: Mitigation | | | | 47 |
| 261 | White Lake, MI | 1973 | Federal: Unknown | 7,931 | | | 48 |
| 262 | White Lake, MI | 1974 | Federal: Unknown | 28,242 | | | 48 |
| 263 | White Lake, MI | 1975 | Federal: Unknown | 25,112 | | | 48 |
| 264 | White Lake, MI | 1976 | Federal: Unknown | 13,667 | | | 48 |
| 265 | White Lake, MI | 1982 | Federal: Mitigation | 38,000 | | \$121,000 | 48 |
| 266 | White Lake, MI | 1985 | Federal: Mitigation | 38,000 | 7,200 | \$222,300 | 19, 48, 47 |
| 267 | White Lake, MI | 1986 | Federal: Mitigation | 80,916 | 11,000 | \$361,000 | 48 |
| 268 | White Lake, MI | 1991 | Federal: Mitigation | 38,000 | 1,300 | \$117,596 | 48, 47 |
| 269 | White Lake, MI | 1995 | Federal: Mitigation | 33,840 | 3,900 | | 48, 47 |
| 270 | Pentwater, MI | 1980 | Unknown | 21,129 | | \$72,855 | 18 |
| 271 | Pentwater, MI | 1981 | Unknown | 23,088 | | \$57,546 | 18 |
| 272 | Pentwater, MI | 1982 | Unknown | 14,004 | | \$49,788 | 18 |
| 273 | Pentwater, MI | 1983 | Federal: Navigation | 21,300 | 2,500 | \$58,333 | 18, 48, 47 |
| 274 | Pentwater, MI | 1984 | Federal: Navigation | 20,166 | 2,500 | \$60,066 | 18, 48, 47 |
| 275 | Pentwater, MI | 1985 | Federal: Navigation | 11,242 | 2,500 | \$90,230 | 19, 48, 47 |
| 276 | Pentwater, MI | 1986 | Federal: Navigation | 23,098 | 2,500 | \$74,536 | 19, 48 |
| 277 | Pentwater, MI | 1987 | Federal: Navigation | 20,784 | 2,500 | \$85,451 | 19, 48 |
| 278 | Pentwater, MI | 1988 | Federal: Navigation | 16,124 | 2,500 | \$70,643 | 19, 48, 47 |
| 279 | Pentwater, MI | 1989 | Federal: Navigation | 19,100 | 2,500 | \$105,727 | 19, 48, 47 |
| 280 | Pentwater, MI | 1990 | Federal: Navigation | 14,209 | 2,500 | \$73,651 | 48, 47 |
| 281 | Pentwater, MI | 1991 | Federal: Navigation | 23,204 | 2,500 | \$95,428 | 48, 47 |
| 282 | Pentwater, MI | 1992 | Federal: Navigation | 24,000 | 2,500 | \$82,018 | 48, 47 |
| 283 | Pentwater, MI | 1993 | Federal: Navigation | 7,941 | 1,700 | \$46,611 | 48, 47 |
| 284 | Pentwater, MI | 1994 | Federal: Navigation | 11,062 | 2,500 | \$63,582 | 48, 47 |
| 285 | Pentwater, MI | 1995 | Federal: Navigation | 15,406 | 2,500 | \$74,862 | 48, 47 |
| 286 | Pentwater, MI | 1996 | Federal: Navigation | | | | 47 |
| 287 | Ludington, MI | 1973 | Federal: Unknown | 20,781 | | | 48 |
| 288 | Ludington, MI | 1974 | Federal: Unknown | 41,654 | | | 48 |
| 289 | Ludington, MI | 1975 | Federal: Unknown | 40,529 | | | 48 |
| 290 | Ludington, MI | 1976 | Federal: Unknown | 9,282 | | | 48 |
| 291 | Ludington, MI | 1977 | Federal: Unknown | 30,448 | | | 48 |
| 292 | Ludington, MI | 1978 | Federal: Mitigation | 736,357 | | | 48 |
| 293 | Ludington, MI | 1978 | Federal: Mitigation | 24,670 | | | 48 |
| 294 | Ludington, MI | 1984 | Federal: Mitigation | 43,825 | | \$157,725 | 18, 48, 47 |
| 295 | Ludington, MI | 1985 | Federal: Mitigation | 175,648 | 4,000 | \$769,334 | 19, 48, 47 |

Table 1. Continued.

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|------------------|------|----------------------|--------------------|---------------|-------------|------------|
| 296 | Ludington, MI | 1989 | Federal: Mitigation | 60,512 | | \$369,790 | 48, 47 |
| 297 | Ludington, MI | 1991 | Federal: Mitigation | 78,070 | 3,500 | \$494,871 | 48, 47 |
| 298 | Ludington, MI | 1993 | Federal: Mitigation | 38,505 | 3,500 | \$215,131 | 48, 47 |
| 299 | Ludington, MI | 1995 | Federal: Mitigation | 29,085 | 2,900 | \$179,568 | 48, 47 |
| 300 | Manistee, MI | 1974 | Federal: Unknown | 23,926 | | | 48 |
| 301 | Manistee, MI | 1975 | Federal: Unknown | 2,317 | | | 48 |
| 302 | Manistee, MI | 1976 | Federal: Unknown | 23,970 | | | 48 |
| 303 | Manistee, MI | 1977 | Federal: Unknown | 32,977 | | | 48 |
| 304 | Manistee, MI | 1978 | Federal: Unknown | 24,558 | | | 48 |
| 305 | Manistee, MI | 1979 | Federal: Unknown | 31,576 | | | 48 |
| 306 | Manistee, MI | 1980 | Federal: Unknown | 3,720 | | | 48 |
| 307 | Manistee, MI | 1982 | Federal: Unknown | 6,587 | | | 48 |
| 308 | Manistee, MI | 1984 | Federal: Navigation | 26,000 | | \$93,750 | 18, 48, 47 |
| 309 | Manistee, MI | 1986 | Federal: Navigation | 32,506 | 500 | \$168,278 | 2, 48, 47 |
| 310 | Manistee, MI | 1989 | Federal: Navigation | 66,748 | 1,000 | \$256,389 | 2, 48, 47 |
| 311 | Manistee, MI | 1992 | Federal: Navigation | 84,003 | 2,000 | \$249,122 | 48, 47 |
| 312 | Manistee, MI | 1993 | Federal: Navigation | 4,420 | 2,000 | \$30,311 | 48, 47 |
| 313 | Manistee, MI | 1994 | Federal: Navigation | 34,705 | | \$88,705(?) | 48, 47 |
| 314 | Portage Lake, MI | 1980 | Unknown | 9,280 | | \$40,512 | 18 |
| 315 | Portage Lake, MI | 1981 | Unknown | 8,780 | | \$49,475 | 18 |
| 316 | Portage Lake, MI | 1989 | Federal: Navigation | 26,564 | 3,000 | \$109,662 | 1, 48, 47 |
| 317 | Portage Lake, MI | 1993 | Federal: Navigation | 28,695 | 3,000 | \$151,555 | 48, 47 |
| 318 | Arcadia, MI | 1980 | Federal: Navigation | 10,876 | | \$39,496 | 18 |
| 319 | Arcadia, MI | 1981 | Federal: Navigation | 11,853 | | \$44,494 | 18 |
| 320 | Arcadia, MI | 1982 | Federal: Navigation | 11,700 | | \$29,608 | 18 |
| 321 | Arcadia, MI | 1983 | Federal: Navigation | 7,920 | 800 | \$26,297 | 48, 47 |
| 322 | Arcadia, MI | 1984 | Federal: Navigation | 18,690 | 800 | \$33,323 | 18, 48, 47 |
| 323 | Arcadia, MI | 1985 | Federal: Navigation | 6,919 | 800 | \$43,730 | 19, 48, 4 |
| 324 | Arcadia, MI | 1986 | Federal: Navigation | 7,102 | 500 | \$43,730 | 19, 48 |
| 325 | Arcadia, MI | 1987 | Federal: Navigation | 11,572 | 800 | \$47,577 | 19, 48 |
| 326 | Arcadia, MI | 1988 | Federal: Navigation | 6,573 | 2,800 | \$28,814 | 19, 48, 47 |
| 327 | Arcadia, MI | 1989 | Federal: Navigation | 5,224 | 700 | \$28,918 | 19, 48, 47 |
| 328 | Arcadia, MI | 1990 | Federal: Navigation | 2,414 | 700 | \$12,500 | 48, 47 |
| 329 | Arcadia, MI | 1991 | Federal: Navigation | 2,888 | 2,500 | \$11,877 | 48, 47 |
| 330 | Arcadia, MI | 1992 | Federal: Navigation | 3,703 | 700 | \$12,655 | 48, 47 |
| 331 | Arcadia, MI | 1993 | Federal: Navigation | 4,384 | 400 | \$29,126 | 48, 47 |
| 332 | Arcadia, MI | 1994 | Federal: Navigation | 3,500 | 700 | \$43,742 | 48, 47 |
| 333 | Arcadia, MI | 1995 | Federal: Navigation | 3,896 | 1,000 | \$24,776 | 48, 47 |
| 334 | Arcadia, MI | 1996 | Federal: Navigation | | | | 47 |
| 335 | Frankfort, MI | 1972 | Federal: Navigation | 23,132 | | | 48 |
| 336 | Frankfort, MI | 1973 | Federal: Navigation | 42,357 | | | 48 |
| 337 | Frankfort, MI | 1974 | Federal: Navigation | 30,227 | | | 48 |
| 338 | Frankfort, MI | 1975 | Federal: Navigation | 20,718 | | | 48 |
| 339 | Frankfort, MI | 1977 | Federal: Navigation | 6,552 | | | 48 |
| 340 | Frankfort, MI | 1978 | Federal: Navigation | 24,263 | | | 48 |
| 341 | Frankfort, MI | 1979 | Federal: Navigation | 24,190 | | | 48 |
| 342 | Frankfort, MI | 1993 | Federal: Navigation | 11,665 | 1,500 | \$47,519 | 48, 47 |
| 343 | Frankfort, MI | 1994 | Federal: Navigation | 24,777 | 1,500 | \$125,550 | 48, 47 |
| 344 | Leland, MI | 1980 | Federal: Unspecified | 14,654 | | \$52,995 | 18 |
| 345 | Leland, MI | 1981 | Federal: Unknown | 13,458 | | \$46,609 | 18 |

Table 1. *Continued.*

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|-----------------------------|-----------|----------------------------|-----------------------|------------------|--------------|------------|
| 346 | Leland, MI | 1982 | Federal: Unknown | 19,099 | | \$47,457 | 18 |
| 347 | Leland, MI | 1983 | Federal: Navigation | 12,686 | 2,500 | \$68,559 | 18, 48, 47 |
| 348 | Leland, MI | 1984 | Federal: Navigation | 12,836 | 2,500 | \$58,000 | 18, 48, 47 |
| 349 | Leland, MI | 1985 | Federal: Navigation | 15,384 | 1,700 | \$48,966 | 19, 48, 47 |
| 360 | Leland, MI | 1986 | Federal: Navigation | 24,881 | 1,700 | \$90,063 | 19, 48, 47 |
| 351 | Leland, MI | 1987 | Federal: Navigation | 16,630 | 1,700 | \$68,373 | 19, 48, 47 |
| 352 | Leland, MI | 1988 | Federal: Navigation | 16,680 | 1,700 | \$100,601 | 19, 48, 47 |
| 353 | Leland, MI | 1989 | Federal: Navigation | 16,471 | 1,700 | \$90,876 | 19, 48, 47 |
| 354 | Leland, MI | 1990 | Federal: Navigation | 17,358 | 1,700 | \$89,866 | 48, 47 |
| 355 | Leland, MI | 1991 | Federal: Navigation | 18,849 | 1,700 | \$77,518 | 48, 47 |
| 356 | Leland, MI | 1992 | Federal: Navigation | 19,409 | 1,700 | \$66,329 | 48, 47 |
| 357 | Leland, MI | 1993 | Federal: Navigation | 9,786 | 700 | \$55,291 | 48, 47 |
| 358 | Leland, MI | 1994 | Federal: Navigation | 9,441 | 1,700 | \$44,824 | 48, 47 |
| 359 | Leland, MI | 1995 | Federal: Navigation | 13,803 | 1,700 | \$67,074 | 48, 47 |
| 360 | Leland, MI | 1996 | Federal: Navigation | | | | 47 |
| | Lake Ontario | | | | | | |
| 361 | Hamlin Beach State Park, NY | 1974-1975 | Federal: Storm and Erosion | 317,000 | 4,250 | \$1,177,800 | 42, 37, 31 |
| 362 | Irondequoit, NY | 1988 | Federal: Unknown | | | | 47 |
| 363 | Irondequoit, NY | 1993 | Federal: Unknown | 11,142 | | \$105,294 | 47 |
| | Lake Superior | | | | | | |
| 364 | Duluth | 1975 | Federal: Navigation | 38,400 | | | 48 |
| 365 | Duluth | 1983 | Federal: Navigation | | | | 48 |
| 366 | Duluth | 1984-1985 | Unknown | 24,344 | | \$161,366 | 18 |
| 367 | Duluth | 1996 | Federal: Navigation | | | | 47 |
| 368 | Superior, WI | 1990 | Federal: Navigation | 45,303 | 2,600 | \$501,178 | 48, 47 |
| 369 | Port Wing Hbr, WI | 1993 | Federal: Navigation | 20,457 | 800 | \$77,121 | 48, 47 |
| 370 | Cornucopia Hbr, WI | 1992 | Federal: Navigation | 7,848 | 300 | \$36,948 | 48, 47 |
| 371 | Black River, MI | 1988 | Federal: Unknown | 8,140 | 800 | \$52,513 | 19, 48 |
| 372 | Black River, MI | 1992 | Federal: Navigation | 8,600 | 800 | \$33,423 | 48, 47 |
| 373 | Black River | 1995 | Federal: Unknown | 5,208 | 800 | \$43,090 | 48, 4 |
| 374 | Ontonagon, MI | 1981 | Federal: Navigation | 109,114 | | \$513,892 | 18 |
| 375 | Ontonagon, MI | 1982 | Federal: Navigation | 87,511 | | \$353,938 | 18 |
| 376 | Ontonagon, MI | 1983 | Federal: Navigation | 25,807 | | \$183,301 | 18, 47 |
| 377 | Ontonagon, MI | 1984 | Federal: Navigation | 27,889 | | \$134,122 | 18 |
| 378 | Ontonagon, MI | 1985 | Federal: Navigation | 51,268 | 6,600 | \$291,454 | 19, 48, 47 |
| 379 | Ontonagon, MI | 1986 | Federal: Navigation | 127,438 | 6,600 | \$474,039 | 19, 48, 47 |
| 380 | Ontonagon, MI | 1986 | Federal: Navigation | 35,037 | 6,600 | \$144,900 | 48, 47 |
| 381 | Ontonagon, MI | 1987 | Federal: Navigation | 54,101 | 7,392 | \$260,680 | 19, 48, 47 |
| 382 | Ontonagon, MI | 1988 | Federal: Navigation | 62,852 | 7,600 | \$237,993 | 19, 48, 47 |
| 383 | Ontonagon, MI | 1989 | Federal: Navigation | 42,278 | 6,600 | \$270,490 | 19, 48, 47 |
| 384 | Ontonagon | 1990 | Federal: Navigation | 57,942 | 7,720 | \$363,973 | 48, 47 |
| 385 | Ontonagon | 1991 | Federal: Navigation | 17,911 | 6,992 | \$136,401 | 48, 47 |
| 386 | Ontonagon | 1992 | Federal: Navigation | 30,676 | 7,720 | \$207,066 | 48, 47 |
| 387 | Ontonagon | 1993 | Federal: Navigation | 62,726 | 7,720 | \$216,258 | 48, 47 |
| 388 | Ontonagon | 1994 | Federal: Navigation | 27,115 | 6,720 | \$277,230 | 48, 47 |
| 389 | Ontonagon | 1995 | Federal: Navigation | 27,025 | 6,720 | \$235,025 | 48, 47 |
| 390 | Ontonagon | 1996 | Federal: Navigation | | | | 47 |
| 391 | Lac LaBelle Hbr, MI | 1994 | Federal: Navigation | 5,005 | | \$30,459 | 48, 47 |
| 392 | Grand Traverse, MI | 1980 | Unknown | 2,271 | | \$4,531 | 18 |
| 393 | Grand Traverse, MI | 1982 | Federal: Navigation | 9,072 | 1,500 | | 48 |

Table 1. Continued.

| # | Beach Location | Date | Funding Type | Volume (cu. yards) | Length (feet) | Cost (\$) | References |
|-----|--------------------|------|---------------------|-----------------------|------------------|--------------|------------|
| 394 | Grand Traverse, MI | 1987 | Federal: Navigation | 11,482 | 1,500 | \$59,216 | 19, 48 |
| 395 | Grand Traverse, MI | 1991 | Federal: Navigation | 8,791 | 1,000 | \$58,143 | 48, 47 |
| 396 | Grand Traverse, MI | 1995 | Federal: Navigation | 9,248 | 1,600 | \$74,216 | 48, 47 |
| 397 | Big Bay, MI | 1980 | Unknown | 4,463 | | \$19,551 | 18 |
| 398 | Big Bay, MI | 1987 | Federal: Navigation | 23,898 | 1,700 | \$123,249 | 19, 48, 47 |
| 399 | Big Bay, MI | 1991 | Federal: Navigation | 9,786 | 1,700 | \$44,805 | 48, 47 |
| 400 | Big Bay, MI | 1995 | Federal: Navigation | 9,977 | 6,700 | | 48, 47 |
| 401 | Presque Isle, MI | | | 8,300 | | \$85,827 | 18, 48, 47 |
| 402 | Little Lake, MI | 1981 | Federal: Navigation | 21,439 | | \$104,411 | 18 |
| 403 | Little Lake, MI | 1982 | Federal: Navigation | 16,506 | | \$71,177 | 18 |
| 404 | Little Lake, MI | 1983 | Federal: Navigation | 12,569 | | \$94,947 | 18, 47 |
| 405 | Little Lake, MI | 1984 | Federal: Navigation | 18,804 | | \$109,562 | 18, 47 |
| 406 | Little Lake, MI | 1985 | Federal: Navigation | 38,368 | 1,800 | \$224,451 | 19, 48, 47 |
| 407 | Little Lake, MI | 1986 | Federal: Navigation | 15,980 | 1,800 | \$130,693 | 19, 48, 47 |
| 408 | Little Lake, MI | 1987 | Federal: Navigation | 26,451 | 2,000 | \$136,416 | 19, 48 |
| 409 | Little Lake, MI | 1988 | Federal: Navigation | 20,685 | 1,800 | \$105,671 | 19, 48, 47 |
| 410 | Little Lake, MI | 1989 | Federal: Navigation | 19,812 | 1,800 | \$88,210 | 19, 48, 47 |
| 411 | Little Lake, MI | 1990 | Federal: Navigation | 24,402 | 1,800 | \$100,645 | 48, 47 |
| 412 | Little Lake, MI | 1991 | Federal: Navigation | 24,962 | 1,800 | \$91,821 | 48, 47 |
| 413 | Little Lake, MI | 1992 | Federal: Navigation | 15,895 | 1,300 | \$66,941 | 48, 47 |
| 414 | Little Lake, MI | 1993 | Federal: Navigation | 8,996 | 1,300 | \$41,268 | 48, 47 |
| 415 | Little Lake, MI | 1994 | Federal: Navigation | 12,596 | | \$74,086 | 48, 47 |
| 416 | Little Lake, MI | 1995 | Federal: Navigation | 8,097 | 1,300 | | 48, 47 |

Table 1. Continued.

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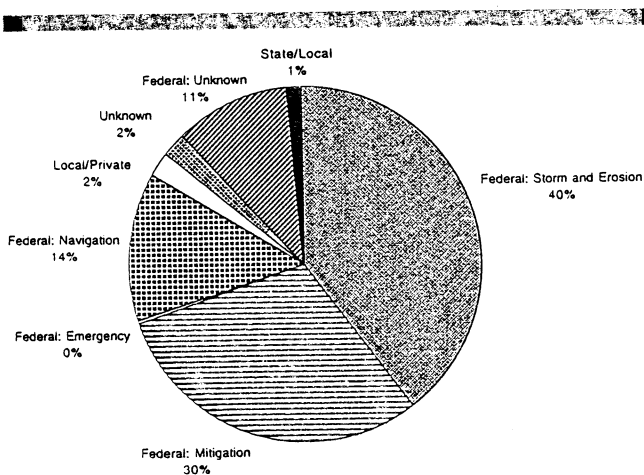


Figure 2. Funding sources of Great Lakes nourishment episodes expressed as a percent of total sand volume (1950-1996).

total volume of both the East and Gulf Coasts (see VALVERDE and PILKEY, and TREMBANIS and PILKEY, in this issue).

The distribution of funding sources for Great Lakes nourishment sources also differs greatly from that of other coastlines. Of the total nourishment volume identified, 90% was funded in part by federal dollars (see Figure 2). This is amount of federal participation is approximately 30% larger than on all other coastlines examined. This greater proportion of federally funded projects is due in part to the large number of federal navigation and federal mitigation projects in the region. Further explanation of the characteristics of Federal Navigation, Federal Mitigation projects follows below.

Navigation beaches are constructed by the dumping of dredge spoil from navigational projects (mostly harbor maintenance dredging) on a nearby beach or in the extreme near-shore area. In most cases beach disposal is chosen because it is the cheapest means available. There have been 135 federal navigation episodes identified in the Great Lakes. They account for 32% of all nourishment episodes in the region. In addition to federally sponsored projects, some municipalities (such as Evanston, Illinois and Ashtabula, Ohio) also use such a strategy for beach nourishment, albeit on a smaller scale, by placing the sand that is dredged from the municipal small boat harbor onto nearby municipal beaches.

Similarly, there have been 124 federal mitigation episodes identified in the Great Lakes, accounting for 30% of all nourishment episodes identified. A mitigation project is undertaken by the USACE when it is found that federal navigational structures (*i.e.* harbor jetties) are interrupting the normal littoral drift of sand, robbing downdrift beaches of sediment and leading to increased erosion rates. These projects were initially funded by Section 111 of the Rivers and Harbors Act of 1968, and are referred to as section 111 projects. There are 10 federal section 111 projects on the Great Lakes, all of which are in Michigan. Most of these projects started in the late 1970's, with St. Joseph being the first. As part of the certification process for a section 111 project, the USACE conducts surveys to determine just how much sand is being in-

tercepted by the navigational structures. Ideally, this amount of sand is to be added annually to the beaches/littoral system downdrift of the interfering structures. However, due to budget constraints (appropriations from Congress) and other factors, this is not usually the case.

The sand for section 111 beach nourishment projects can come from either harbor dredging or it is trucked in from near-by sand pits. The beaches constructed are termed feeder beaches and are expected to be unstable and erode, furnishing sand to the littoral system that was lost to the interfering structures. In Michigan, the section 111 program has had varied degrees of success in slowing erosion—from failure in St. Joseph to success in Lexington. Failure in St. Joseph occurred when the volume of sand used in the creation of feeder beaches was not great enough to cover the consolidated clays that are naturally found beneath the layer of sand in the southeastern portion of Lake Michigan. When the sand layer is lost to erosion, the clay material is exposed to weathering and erodes at a rapid rate. This has happened in Shoreham, about 1 mile south (downdrift) of St. Joseph Harbor. In Lexington, however, the beach has grown in width immediately south of the harbor.

Federal Storm and Erosion control nourishment projects in the Great lakes region tend to create small heavily protected (through groins and breakwaters) pocket beaches. In these type of projects, most sand is expected to stay within the beach unit and the beach is designed and constructed to "work" with hard structures. Examples of such projects are Forest Park in Lake Forest, Illinois (1986) and Lakeview Park in Lorain, Ohio (1977). The huge (by Great Lakes standards) 1992 project at Presque Isle State Park, Pennsylvania, can be viewed as giant-sized version of these smaller projects. The 55 offshore detached breakwaters are causing more downdrift (east) erosion than predicted in design documents, and as a result nourishment requirements are larger than anticipated.

The cumulative volume graph (Figure 3) for the Great Lakes region shows that since the 1960's, every decade has seen a greater total nourishment volume added to Great Lakes beaches than its predecessor. The 1990's seem to continue this trend with 4.5 million cubic yards emplaced by mid-1996, which is already over half of the 8.8 million emplaced during the 1980's.

FUTURE OUTLOOK

The increase in water quality of Lake Michigan and Erie have made the beaches here more attractive for recreational use, putting increased demands on existing public beaches. There may be an increase in demand for more beaches and to maintain the ones that already exist. This, along with the "success" of pocket beach projects like the one in Lake Forest, Illinois, may lead to construction of more of these facilities, or the nourishment of more traditional pocket beaches (such as those in Chicago). However, construction of a breakwater and beachfill is an expensive undertaking and out of the price range of most municipalities. Additionally, these types of projects often lead to downdrift erosion as is occurring at Lake Forest, Illinois. The continued construction of such projects

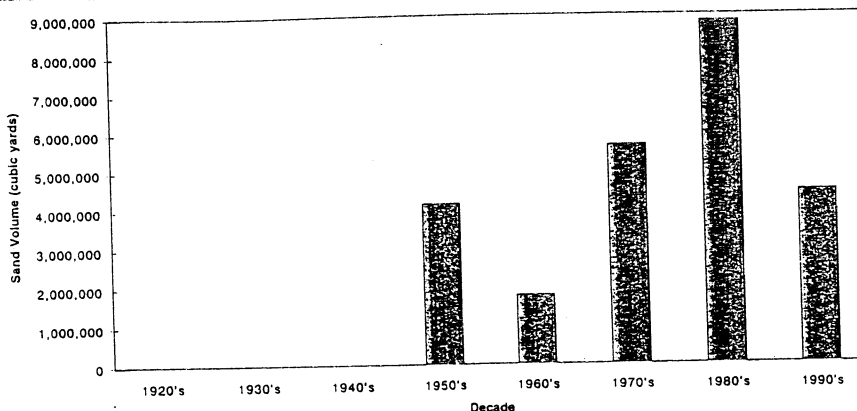


Figure 3. Total volume of nourishment sand placed on Great Lakes coastlines per decade.

is ultimately decided by the attitude of the United States Congress. Under current budgetary constraints, it is most likely that such projects will be forgone, and other methods of erosion control such as traditional hard stabilization (*i.e.* seawalls and groins) will be constructed.

Dredge spoil disposal projects can also be expected to continue, and possibly increase as spoil becomes cleaner and states, aware of the less deleterious effects of this disposal method, ask the USACE to dispose of material in this manner (and in some cases amend their laws to require it).

FURTHER INFORMATION

In order to facilitate greater use of this database for research purposes, our records may be obtained either by contacting the authors directly or by accessing our web-site <http://www.geo.duke/psds.htm>. The authors gladly invite the submission of corrections and/or additions to the database.

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