REVIEW REPORT ON

NEW BUFFALO HARBOR
MICHIGAN

U.S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK ST.
CHICAGO 5, ILLINOIS

AUGUST 1961

NO. 60

NCDED-R (1 Aug 61-NCWED-R) 1st Ind
SUBJECT: Review Report on New Buffalo Harbor, Michigan

U. S. Army Engr Div, North Central, Chicago, Illinois 16 February 1962

TO: Res. Mbr. Bd. of Engrs. for Rivers and Harbors, Washington, D. C.

I concur in the recommendations of the District Engineer.

J. A. SMEDILE
Colonel, Corps of Engineers
Acting Division Engineer

NEW BUFFALO HARBOR, MICHIGAN

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SYLLABUS

The District Engineer concludes that New Buffalo Harbor, Michigan is worthy of improvement by the United States. He recommends dredging of an entrance channel 10 feet deep and 80 to 180 feet wide to the mouth of the Galien River, construction of breakwaters, and dredging of an inner channel 8 feet deep and 80 feet wide in the Galien River. The recommendation is made subject to certain requirements of local cooperation, including a cash contribution of 48 percent of the actual first cost of general navigation facilities, presently estimated (August 1961) at $615,000. The first cost to the United States is estimated to be $667,000 and the annual cost of maintenance $21,000. The District Engineer determines that tangible benefits resulting from gains in recreational value to owners of pleasure boats using New Buffalo Harbor, reduced damages to recreational boats, reduced cost of channel maintenance to local interests, and increased commercial fish catch, will justify the recommended improvement. The District Engineer further recommends that the original project for improvement of New Buffalo Harbor, adopted in 1857, be abandoned.

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REVIEW REPORT ON
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DRAWING

Plate No.

1 Plan of improvement, File No. 57-R2/2A

APPENDIXES

A - Hydraulic analysis for breakwater design
B - Discussion of design and cost estimates
C - Effect of proposed harbor on shoreline
D - Correspondence

ATTACHMENT 1

Information called for by S. R. 148, 85th Congress.

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

NCWED-R

1 August 1961

SUBJECT: Review Report on New Buffalo Harbor, Michigan

TO: Division Engineer
U. S. Army Engineer Division, North Central
Chicago, Illinois

AUTHORITY

1. This report is submitted in compliance with the following resolutions adopted by the Committee on Public Works, United States Senate, 20 June 1957, and by the Committee on Public Works of the House of Representatives, United States, 16 July 1958, as follows:

"RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the reports of the Chief of Engineers on the Coasts of the Great Lakes-Harbors of Refuge for Light-Draft Vessels, published as House Document Numbered 446, Seventy-eighth Congress, Second session, and other reports, with a view to determining whether the recommendations contained therein should be modified in any way at the present time, with respect to improvement of the existing harbor at New Buffalo, Michigan."

"Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors, be, and is hereby, requested to review the reports on the Coasts of the Great Lakes-Harbors of Refuge for Light-Draft Vessels, published as House Document Numbered 446, 78th Congress, Second session, and other reports, with a view to determining whether the recommendations contained therein should be modified in any way at the present time, with respect to improvements of the existing harbor at New Buffalo, Michigan."

PURPOSE AND EXTENT OF STUDY

2. This report is limited to investigation of the advisability of improvement of New Buffalo Harbor in the interest of light-draft navigation, and to determination of the extent of local cooperation required. Investigations consisted of obtaining topographic, hydrographic and foundation data and the securing of all available commercial statistics. Wave studies were made to determine the best and most economical plan to accomplish the desired results. In the course of the study, local interests and governing bodies were consulted and interested Federal and state agencies were requested to review the considered plan of improvement. Their views and comments are set forth in paragraphs 54 and 55. A public hearing was held at New Buffalo, Michigan on 17 February 1959, at which statements of the opinions and desires of local interests were received as described in paragraphs 17 to 20.

DESCRIPTION

3. LOW WATER DATUM

Depths mentioned herein are referred to low-water datum for Lake Michigan, which is 578.5 feet above mean tide at New York. Depths shown on United States Lake Survey charts for the region of New Buffalo Harbor and Lake Michigan also are referred to this datum.

4. GENERAL

New Buffalo Harbor, Michigan, is located at the mouth of the Galien River on the southeast shore of Lake Michigan, about 45 miles easterly from Chicago. Nearest harbors are at Michigan City, Indiana, 10 miles southwest, and St. Joseph, Michigan, 25 miles northeast. Both are Federally improved commercial harbors having additional facilities for fishing and recreational craft. Michigan City Harbor has a Federally improved yacht basin adjacent to the outer harbor. The village of New Buffalo is about 2,000 feet landward of the lake shore and is separated from it by sand hills and a marsh known as Lake Pottawatomie through which the Galien River meanders, flowing into Lake Michigan at a point directly opposite the village. Berthing and service facilities for recreational boats are located along the Galien River above and below the Whitaker Street bridge, and at two marinas located on artifically dredged channels entering the river near its mouth. The principal features of the nearby municipal park are a public pleasure boat launching ramp and bathing beach adjacent to the northerly shore of the Galien River. A large number of pleasure boats use the harbor as a regular base or port of call for a season of about 7 months, generally April through October.

5. NAVIGATION CONDITIONS

Between Michigan City and St. Joseph, depths of 30 feet or more lie about five-eighths of a mile offshore. Soundings over an area extending about 2,800 feet alongshore and 1,400 feet offshore show depths ranging from 1 to 18 feet. The lower two-mile reach of the Galien River provides a fine natural harbor for light-draft vessels. Due to wave action, a bar forms at the river mouth with controlling depths of not more than 2 feet. Adjacent to the river mouth are the remnants of two old piers and bulkheads.

6. WATER LEVELS

Ordinary fluctuations of water level at New Buffalo Harbor are of the same magnitude and frequency as apply generally to other harbors on Lake Michigan. The lowest seasonal lake stages prevail during the winter months and the highest during the summer months. In the five-year period 1956-1960, monthly mean stages of Lake Michigan ranged between 2.50 feet above and 0.83 foot below low water datum. In the 101-year period, 1860-1960, the highest monthly mean stage was 5.18 feet above low water datum and the lowest 1.15 feet below; a range of 6.33 feet. The greatest annual fluctuation between the highest and lowest monthly mean of any year was 2.23 feet; the least 0.36 foot. Occasional oscillations of irregular magnitude and duration result from wind and variations in barometric pressure. These changes in water level may range from a few inches to about three feet for periods varying from a few minutes to several hours. New Buffalo Harbor entrance is exposed to seas from the southwest through west to northeast. The maximum fetch, a little east of north, is about 300 miles. The most severe storms on Lake Michigan occur during the fall, winter, and early spring.

7. CHARTS AND MAPS

The location of New Buffalo Harbor and its relation to other ports is shown on United States Lake Survey Coast Chart No. 75. The surrounding territory is shown on United States Geological Survey topographic quadrangle sheet titled "Three Oaks." The map accompanying this report shows the existing facilities and features of the improvement considered.

TRIBUTARY AREA

8. The village of New Buffalo had a 1960 population of 2,100 which is about doubled during the summer by vacationists, the locality being a popular summer resort area. The surrounding area is a fruit growing and agricultural region. New Buffalo is located in the southwest corner of Berrien County, which had a 1960 population of 150,000. Rail transportation, consisting only of freight, is provided by the Chicago-Detroit mainlines of the Chesapeake and Ohio Railway and the New York Central Railroad which pass through the village. Passenger service is provided by the motor-coach division of the Chicago South Shore and South Bend Railroad which connects with the railroad at Michigan City, Indiana. U. S. Highways No. 12 and 212 pass through New Buffalo. A

secondary highway connects with the Indiana East-West Tollroad about 10 miles south. Interstate Highway No. 94, a limited-access freeway from Detroit, is near the eastern limits of New Buffalo. There is no major industry or natural resource, the principal occupation being general trade. Waterborne commerce at New Buffalo Harbor consists of commercial fishing and recreational boating. The principal towns in the vicinity, with their 1960 populations, are Michigan City, Indiana, 10 miles southwest, 37,000; South Bend, Indiana, 27 miles southeast, 132,000; Niles, Michigan, 25 miles east, 14,000; and Benton Harbor-St. Joseph, Michigan, 25 miles northeast, 31,000.

BRIDGES

9. No bridges cross that portion of New Buffalo Harbor under consideration herein for improvement. Immediately upstream at mile 0.3 above the mouth of the Galien River is the Whitaker Street bridge. This is a fixed through-truss structure with a clear span of 105 feet between abutments. The elevation of low steel is 8.3 feet above low water datum. The village of New Buffalo has tentative plans to remove this bridge and replace it with a new bridge farther upstream. Pleasure boats other than masted craft regularly pass the existing bridge with no reported difficulties.

PRIOR REPORTS

10. Three survey reports and two preliminary examination reports have been published on New Buffalo Harbor during the period 1854-1918. In 1936 an unfavorable preliminary examination report was submitted but not published. In 1944 the survey report here under review was published as House Document No. 446, 78th Congress, 2d Session, entitled "The Coasts of the Great Lakes - Harbors of Refuge for Light-Draft Vessels." Improvement of New Buffalo Harbor, among others, was considered therein with a view to establishment of a harbor of refuge. The report concluded that existing harbors provided reasonable safety for light-draft vessels cruising in the southerly part of Lake Michigan and recommended that no project for improvement of New Buffalo Harbor be adopted at that time.

EXISTING CORPS OF ENGINEERS' PROJECT

11. There is no active existing project for improvement of New Buffalo Harbor. The original project, which was adopted in 1857, provided for a revetted entrance channel 200 feet wide and 12 feet deep through the sand hills between Lake Michigan and the Lake Pottawatomie marshes. Construction and dredging were carried on intermittently from 1866 to 1885. Those operations resulted in a partially revetted channel 1,400 feet long,

40 feet wide, and 6 feet deep which substantially forms the present entrance channel. No work has been done since 1885. The project was recommended for abandonment in 1898 but no action was taken by Congress. Further recommendation for abandonment is considered in a later section of this report. Total costs to the United States, to and including fiscal year 1886, were $83,000. There were no expenditures for maintenance.

LOCAL COOPERATION ON EXISTING PROJECT

12. No local cooperation has been required by the United States in connection with the authorized improvement.

OTHER IMPROVEMENTS

13. LOCAL INTERESTS

Since 1954 local interests have expended $30,000 on channel improvements for the benefit of general navigation. At a cost of $16,000, a timber jetty north of and lakeward of the mouth of the river was constructed to protect the entrance channel from shoaling. In addition, about $12,000 has been spent for periodic dredging of the shoal at the mouth of the river in efforts to maintain a usable depth of channel during the recreational boating season. In 1960, local marina operators constructed additional docks, channel improvements, and shower and washroom facilities at an estimated cost of $270,000. The Gary Boat Club has under construction complete facilities estimated to cost $105,000. The New Buffalo Yacht Club proposes to construct a clubhouse at a cost of $39,000.

14. MICHIGAN STATE WATERWAYS COMMISSION

In 1960 the Michigan State Waterways Commission allotted $3,000 for interim channel maintenance at the harbor. A required matching amount was appropriated by the village. However the state funds were received too late for effective use in the 1960 boating season and their expenditure was deferred until the 1961 season. In November 1960 the timber jetty at the mouth of the river was damaged. Local interests are planning to repair it at an estimated cost of $4,500.

TERMINAL AND TRANSFER FACILITIES

15. PUBLIC

The village of New Buffalo owns and operates a boat ramp located on the north bank of the entrance channel, about 700 feet from the lake.

The ramp, built at a cost of $2,000, is of concrete construction and is equipped with a hoist. It is accessible from nearby Whitaker Street, and is available to all at a nominal fee. The village port authority plans to make it available without charge when the construction cost is recovered. There are no other publicly owned docking or mooring facilities. However, the Michigan State Waterways Commission and the village authorities offer assurances that an adequate portion of existing private docking facilities will be kept available to the public at nominal fees. About 470 berths, as described in paragraph 16, are presently available for the existing locally based boats which number approximately 600. Those boats not permanently berthed in the water are stored elsewhere and launched from trailers for each use.

16. PRIVATE

In addition to the public boat ramp there are three privately operated marinas and a private boat club located at the harbor, as follows:

a. Guhl's Boat and Dock Company is located along the north bank of the main channel, about 1,000 feet from the mouth. It is equipped to handle about 70 recreational vessels. Also provided are a stationary vessel lift, boat sale and repair facilities, and complete marine service equipment. No expansion of existing docking facilities is planned.

b. Snug Harbor Marina is located about 3/8 mile south of the Galien River. It is connected to the river by an artificial canal. Berthing is available for approximately 170 vessels. Tractor-trailer equipment for unloading all types of recreational vessels is also available. Sanitary accommodations, including showers, are housed in an adjacent building. Complete dock-side facilities including water, electric power, gasoline and oil, are available at all berths. Additional berths along the canal are under construction for the Gary Boat Club.

c. New Buffalo Marina is under construction along the Galien River immediately above and below the Whitaker Street bridge and in an artificial basin south of the river. About 150 berths with full dockside facilities are presently available adjacent to the bridge. When completed, this marina will accommodate 420 craft and provide complete dockside facilities.

d. The Gary Boat Club has constructed complete pleasure boating facilities along the west bank of the canal to Snug Harbor Marina, including a club house. About 80 slips have been built. Another 100 are soon to be constructed. The club was formerly located at the mouth of Burns Waterway, Indiana, on property now being developed by the Midwest Steel Corporation.

IMPROVEMENTS DESIRED

17. PUBLIC HEARING

A public hearing was held by the District Engineer on 17 February 1959 at New Buffalo, Michigan. It was attended by 100 persons, among whom were the Mayor and other local officials, and municipal officials from neighboring communities. Also in attendance were representatives of other Federal agencies, the Michigan State Waterways Commission, business interests, civic and commercial organizations, railroads, and navigation interests.

18. PRINCIPAL STATEMENTS

Statements in support of improvement of New Buffalo Harbor were received from United States Senators Pat McNamara and Phillip A. Hart. A letter to local interests from the Governor of Michigan, favoring harbor improvement, was introduced into the record. Supporting statements were received also from public officials of Michigan and Indiana, and from navigation and business interests. No opposition to the desired improvements was presented.

19. IMPROVEMENTS DESIRED

The Michigan State Waterways Commission, a state agency established to construct recreational and commercial navigation facilities and to participate with other units of the state and Federal governments, offered to act as sponsor of the improvement. It acknowledged responsibility for the required cash contribution and other items of local cooperation. With the concurrence of local boating interests and the New Buffalo Port Authority, the commission requested the following navigation improvements:

a. Two parallel piers to extend from the shore at the mouth of the Galien River to the 10-foot contour in Lake Michigan.

b. An entrance channel 12 feet deep, from that depth in the lake to a point 500 feet landward from the outer ends of the piers, thence 10 feet deep to the Whitaker Street bridge, all at a width of 80 feet.

20. VIEWS OF LOCAL INTERESTS

The principal reasons advanced by local interests in justification of the desired improvement were:

a. A harbor of refuge for small craft is needed in the reach between Michigan City, Indiana and St. Joseph, Michigan. The distance between these points is 35 miles, which is considered too far for small craft to reach safety in event of a sudden storm.

b. The improvement would be used by interstate as well as locally based craft.

c. The economy of the region would benefit from the increase in traffic.

d. Commercial fishing would be profitable, once fishermen were assured of a safe base of operations.

e. Damages which occur frequently when small boats attempt to enter the harbor under existing conditions would be lessened and insurance rates would be reduced.

f. The Galien River would no longer silt up at the mouth and thus periodic damage from flooding would be eliminated.

EXISTING AND PROSPECTIVE COMMERCE

21. Total waterborne commerce at New Buffalo Harbor consists of a local catch of fish. This has averaged about one ton annually during the period 1949-1958, as reported by the Michigan State Department of Conservation. Existing commercial fishing activities are handicapped by lack of adequate channel depths in the harbor. Provision of such depths together with a protected entrance would increase the number of local fishing boats. A possibility exists that two boats now based at other ports would transfer to New Buffalo, and there is a reasonable certainty that one new boat will be commissioned for local commercial fishing. This is based upon surveys of local and nearby commercial fishing interests. Experience of commercial fishermen at harbors having adequate navigation facilities indicates that a dependable fishing season of about 200 days may be expected annually, with an average daily catch of 500 pounds per boat. Hence, the prospective additional commercial fish catch for one new boat at New Buffalo Harbor would be 200 x 500 = 100,000 pounds, or about 50 tons per year.

VESSEL TRAFFIC

22. EXISTING RECREATIONAL BOATS

No vessel traffic statistics are available for New Buffalo Harbor. Locally based recreational boats make numerous trips into and out of the harbor during the boating season April through October. The harbor is visited by a substantial number of transient pleasure boats each season. As shown in table 1, existing locally based recreational boats number about 600 craft, and existing transient boats about 240. Statistics on the existing and prospective boats are based on the results of a comprehensive questionnaire which was circulated by local interests and by the Michigan State Waterways Commission in connection with this study. Additional information was obtained in subsequent discussions with local boating interests (see paragraph 54).

23. PROSPECTIVE RECREATIONAL BOATS

It is estimated that about 250 boats will be added locally as a result of natural growth and other causes not related to further general improvement of New Buffalo Harbor. This increase will result largely from transfer of boats of the Gary Boat Club. The club, which was formerly located at the mouth of Burns Waterway, Indiana, has established headquarters at New Buffalo. Transfer of member craft will be completed regardless of any further improvement of the harbor. However, full development of the harbor as considered herein would attract about 150 boats now based at other nearby Indiana communities such as Michigan City, South Bend, Elkhart, Muncie, and Gary. These are in addition to those from the Gary Boat Club. It would also induce the purchase of about 50 new boats by local residents and would attract an average of 160 additional visiting boats during the boating season. Table 1 indicates that prospective locally based boats will total about 1,050 and prospective transient boats about 400.

Table 1 - Existing and prospective recreational boats at New Buffalo Harbor

Type of boat	Length, feet	Present local boats	New boats added because of natural growth	New boats added because of improvement	Boats transferred because of improvement	Total prospective local boats	Present transient boats	Additional transient boats	Total prospective transient boats
Outboards	10-20	380	155	30	85	650	-	-	-
Inboards	10-20	60	25	5	15	105	-	-	-
Cruisers	15-30	90	35	8	20	153	170	130	300
Cruisers	31-50	50	15	4	10	79	60	30	90
Auxiliary sailboats	15-30	12	10	2	10	34	10	-	10
Sailboats	10-20	8	10	1	10	29	-	-	-
Totals		600	250	50	150	1,050	240	160	400

DIFFICULTIES ATTENDING NAVIGATION

24. The difficulties attending navigation in New Buffalo Harbor result from inadequate protection at the entrance and insufficient channel depth and width at the mouth of the Galien River. A shifting sandbar which frequently forms at the entrance renders hazardous and unpredictable the passage of any but the shallowest-draft boats at such times. During 1959 and 1960, 25 people were rescued from boats capsized or disabled at the mouth of the river, and one person was drowned.

WATER POWER AND OTHER SPECIAL SUBJECTS

25. The improvements considered in this report would not involve questions of water power, water supply, flood control, irrigation, or abatement of stream pollution.

PLAN OF IMPROVEMENT

26. GENERAL

The plan of improvement considered herein provides for deepening the Galien River channel at its mouth, and for dredging an entrance channel in the lake to be protected by breakwaters. The considered improvements will comply in general with the desires of local interests, and are planned to afford safe entrance conditions into the harbor and satisfactory navigating conditions within the harbor.

27. DESCRIPTION

The plan of improvement shown on the accompanying map provides for two new rubble-mound breakwaters at the harbor entrance with steel sheet piling shore connections; an entrance channel 850 feet long, 80 to 180 feet wide, and 10 feet deep from that depth in the lake to the mouth of the Galien River; and a deepened inner channel in the river, 1,250 feet long, 80 feet wide, and 8 feet deep up to the Whitaker Street bridge. The breakwaters will be about 800 feet apart at the shoreline and 200 feet apart at the outer ends, with overall lengths of 1,400 feet and 860 feet for the north and south breakwaters, respectively. They will enclose an area of about 8 acres in Lake Michigan. The length of beach between the river mouth and the north breakwater, about 300 linear feet, will function as a spending beach.

28. BASIS OF DESIGN

The proposed plan of improvement was developed from analyses of wave refraction and diffraction diagrams and from an examination of various combinations of breakwater types. The converging breakwaters were arranged to enclose a suitable spending beach to reduce wave rebound, the enclosed area being planned as a stilling basin to reduce wave action in the inner harbor. The breakwaters will provide maximum protection against storms from the west through north and northeast. The wave refraction and diffraction studies are described in appendix A to this report. The breakwater design analysis is presented in appendix B.

29. CHANNEL DIMENSIONS

Practicable and serviceable dimensions for the inner channel in the river are considered to be 80 feet in width and 8 feet in depth. These are in general conformity with the dimensions of facilities now available or being provided at other light-draft harbors on the Great Lakes. Necessary additional deepening of the entrance channel through the more exposed area of the outer harbor, to a depth of 10 feet, will be provided as shown on the accompanying map. A turning basin is not required for the considered plan of improvement. Navigation clearances in the Galien River along the existing and proposed berthing facilities, and in the marina basins completed or under construction south of the river, are adequate to permit safe maneuvering of shallow-draft recreational boats.

30. REMEDIAL MEASURES FOR SHORELINE EROSION

The remedial measures considered herein are needed to counteract the increased beach erosion expected to be caused by the harbor structures. This will restrict erosion to no more than the existing rate. These measures consist of a stockpile of beach materials to be placed on the shore about 0.3 mile south of the harbor. From there the stockpile material will be distributed naturally by waves and currents. The stockpile will be established with the initial channel dredging spoil and with material dredged from the bottom of Lake Michigan north of the proposed harbor entrance. At about the third year after construction of the project the stockpile will be replenished. It is estimated that the impounding area to be formed by the north breakwater will be filled in approximately five years. Then the littoral drift will again bypass the harbor by natural means. After that time, the spoil from periodic channel maintenance dredging will be placed on the stockpile. It is expected that all initial borrow and maintenance dredging will be done by hydraulic pipeline dredge. Remedial measures are described in detail in appendix C.

31. LANDS AND RIGHT-OF-WAY

Dredging of the inner channel in the Galien River will require provision of approximately 1/2 acre of right-of-way between the river mouth and the Whitaker Street bridge, along the south bank of the river. Construction of the breakwaters will require approximately 1/2 acre of land to provide for the shore connections. Local interests will be required to provide an area of 2 acres for the beach nourishment stockpile. Bridge alterations and utility relocations will not be required under the considered plan of improvement.

32. OTHER REQUESTED IMPROVEMENTS

Consideration was given in this study to the plan requested by the project sponsors, which contemplated channel depths of 10 and 12 feet and closely spaced parallel entrance piers with the entrance facing due north. It was determined that the parallel piers would conduct storm waves through the confined channel into the inner harbor, instead of allowing the waves to expand and lose force in a wave-stilling basin. The requested entrance, facing north, would admit the most critical refracted storm waves, which were determined to approach from the north through northwest. It was further found that a safe draft for the prospective vessel traffic would be afforded by lesser channel depths than requested, and that no additional benefits would accrue to the greater depths. Therefore, the requested channel depths and arrangement of protective structures were not adopted for the plan of improvement considered herein.

SHORELINE CHANGES

33. The predominant littoral drift at and near New Buffalo is from the northeast as evidenced by accretion of beach material which has occurred to the north of the pile pier north of the river mouth. Short-time reversals in direction of drift are indicated by sand deposits south of the harbor entrance. Accretion is expected to occur along the shoreline for at least one mile north of the considered north breakwater. Beyond a small fillet of accretion expected to form at the south breakwater, an increase in erosion will occur along approximately 3 miles of shoreline to the south of the harbor. Effects of the considered improvement on the shoreline are discussed in detail in appendix C.

REQUIRED AIDS TO NAVIGATION

34. The United States Coast Guard was consulted concerning the necessity and cost of navigation aids for the considered harbor improvement. The estimated cost of establishing lights and buoys would be $5,000 with annual maintenance estimated at $500.

ESTIMATE OF FIRST COST

35. FEDERAL

A detailed estimate of costs and quantities for the considered plan of improvement is presented in appendix B and summarized in table 2. Excavation includes dredging to the considered project depths of 8 feet and 10 feet, plus one foot over-depth. The general character of the bottom was determined by examination of records of probings which indicated that the material to be excavated is composed of sand and gravel, with some clay near the upper end of the inner channel. It was determined that hydraulic dredging would cost less than dipper dredging if suitable spoil disposal land was furnished by local interests. In this connection, the considered remedial measures for shoreline erosion include provision of a stockpile of dredged materials for beach nourishment, as described in paragraph 30. Therefore, for the purposes of this report it is assumed that all excavated material from initial dredging will be removed by hydraulic dredge and then deposited on the stockpile. Unit prices are based on August 1961 price levels.

36. NON-FEDERAL

The non-Federal cash contribution shown in table 2 is as estimated in paragraph 51. Lands and rights-of-way required for construction of the project, totaling about one acre, will be furnished by the public sponsors of the improvement. In addition, 2 acres of land on the beach south of the harbor will be made available for the beach nourishment stockpile. Non-Federal dredging and construction work to provide mooring areas, piers, mooring piles, clubhouses, and related appurtenances will be required in connection with service facilities to serve prospective traffic. Most of that work is either completed or underway, at a total estimated cost of $414,000. It is considered that costs for such work will be self-liquidating and will be included in service charges.

Table 2 - Estimate of first cost

Item	Amount
Federal first cost	
Excavation, channels and beach nourishment stockpile	$ 230,000
Breakwater construction	898,000
Engineering, design, and model study	70,000
Supervision and administration	84,000
Subtotal, general navigation facilities	1,282,000
Preauthorization study	15,000
Aids to navigation	5,000
Total	1,302,000
Less non-Federal cash contribution	615,000
Total Federal first cost	687,000
Non-Federal first cost	
Cash contribution	615,000
Rights-of-way, 3 acres	21,000
Total non-Federal first cost	636,000
Total first cost	1,323,000

ESTIMATE OF ANNUAL CHARGES

37. A detailed estimate of annual charges for the considered plan of improvement is presented in table 3. It is estimated that construction will require two navigation seasons. The allowance made for interest during construction in determining investment cost is, therefore,

based on a two-year period. Interest is assumed at 2-5/8 percent on Federal expenditures and 3-1/2 percent on non-Federal public expenditures. The non-Federal public interest rate is supported by recent experience in state financing of public works in Michigan. Amortization is based on an assumed project life of 50 years. The annual cost of maintenance to the United States for channels and beach nourishment stockpiling is estimated to be $16,000 and for breakwaters $5,000. For aids to navigation it is estimated to be $500. No charge is made for loss of taxes on land required for rights-of-way.

Table 3 - Estimate of annual charges

Item	Amount
Federal annual charges	
Investment cost:	
Federal first cost	$ 687,000
Interest during construction (2-5/8% for 1/2 of 2-year construction period)	18,000
Total Federal investment	705,000
Interest on investment at 2-5/8%	18,500
Amortization, 50 years at 2-5/8% (0.989%)	7,000
Maintenance:	
Channels and beach nourishment stockpile	16,000
Breakwaters	5,000
Aids to navigation	500
Total Federal annual charges	47,000
Non-Federal annual charges, public	
Investment cost:	
Non-Federal first cost, cash contribution	615,000
Interest during construction (3-1/2% of $615,000 for 1/2 of 2-year construction period)	22,000
Non-Federal first cost, rights-of-way	21,000
Total non-Federal investment	658,000
Interest on investment at 3-1/2%	23,000
Amortization, 50 years at 3-1/2% (0.763%)	5,000
Total non-Federal annual charges	28,000
Total annual charges	75,000

ESTIMATES OF BENEFITS

38. GENERAL

The considered plan of improvement is expected to benefit recreational boating and light-draft commercial fishing through improvement of recreational navigation facilities, reduced damages to light-draft boats, reduced maintenance expense to local interests, and increased commercial fish catch. Benefits accruing to recreational boating are evaluated for the boats anticipated to use the harbor improvements. These are based on the depreciated values of the boats. Benefits due to reduction of losses and damages are evaluated on current prices.

39. BENEFITS, RECREATIONAL NAVIGATION

Recreational benefits are evaluated as the gain in annual return which owners of pleasure craft would receive as a result of the improvement if their boats were used as for-hire vessels. The benefits are equivalent to the net return on the depreciated investment in the boats after all expenses have been paid. Depreciated values are taken as 50 percent of the estimated new cost of the boats, assuming that due to normal turnover, wear and tear, and obsolescence, the average boat normally will have exhausted approximately one-half of its useful life. Where the owner and user are the same, as generally is the case at New Buffalo, the equivalent margin of net return over expense is considered the gage of the minimum additional value received above costs from the boat and the water area used for recreational navigation benefits. An estimate is made of the percent ideal annual for-hire return for the various types of boats expected to use navigation facilities at New Buffalo, considering all pertinent factors. Next an estimate is made of the percent of optimum use of the boats which is received at present by the owners, and the percent of optimum use which could be received with the considered improvements. The difference is the gain in the percent of optimum use. Finally the gain is applied to the total depreciated value of each class of boat to determine the resulting benefit.

40. DISTRIBUTION OF BENEFITS

Benefits from the improvements would accrue not only to the present locally based boats, but also to all craft which would use the harbor over the life of the project. These benefits include those which would accrue to boats added because of natural growth alone, to new craft purchased solely because the improvements provide attractive conditions for boating, to craft transferred from other bases of operation because of the convenience and adequacy of the improvements provided, and to transient craft which would visit the harbor if more adequate facilities were provided. They are discussed in the following paragraphs and are estimated in tables 4 to 8 inclusive. The size and composition of each group of boats shown therein, and the number of boats of each type, are as determined in paragraph 23 and table 1. Benefits for certain classes of boats are reduced by an appropriate percentage which corresponds to the estimated number of days per season spent away on cruise. This takes into account that part of the estimated benefits are made possible by improvements of other harbors.

41. PRESENT WORTH ADJUSTMENT

Estimated benefits for each group of boats are the maximum future benefits to be derived when all boats in the group are using the improvement. It is anticipated that maximum future benefits for new boats added because of improvement and equivalent transient boats would be attained in about 5 years. A long-term private interest rate of 4 percent is assumed in discounting the future benefits and in reducing them to equivalent average annual present worth values, by means of an appropriate growth-pattern factor as shown in tables 6 and 8. It is expected that all present local boats, all boats added because of natural growth, and all boats transferred would begin using the improvement almost as soon as it is completed. Consequently, the maximum future benefits estimated in tables 4, 5 and 7 would be attained almost immediately and would be equivalent to average annual benefits.

42. BENEFITS, PRESENT BOATS AND BOATS ADDED BECAUSE OF NATURAL GROWTH

Present locally based recreational boats using the harbor regularly number about 600. These have a total depreciated value estimated at $976,200. In addition, about 250 locally based boats, having a total estimated depreciated value of $374,500, will be added because of natural growth or other causes regardless of any improvement. Benefits to these craft will result from an increase in the percent of optimum use possible under the improved conditions as compared to present conditions. Because of increased depths in the approach and inner channels it will be possible to operate the boats safely in more unsettled weather in spring and fall and on less favorable sailing days in summer. There will be less delays because of goundings, less damages to boats and motors from operating too close to the channel bottom, and more opportunity to operate with boats loaded to their maximum safe capacities. Therefore, it is estimated that the improvements will afford increases in optimum use of from 20 to 50 percent for the boats. The maximum future benefits to the present locally based boats, and the equivalent average annual benefits, amount to $26,900 annually as shown in table 4. Maximum future benefits to the boats added because of natural growth, and the equivalent average annual benefits, are estimated in table 5 to be $10,300 annually.

Table 4 - Recreational navigation benefits, present locally based boats

Type of craft	Length, feet	No. of boats	Depreciated value		Percent return					On cruise (150-day season)		
						% of ideal						
			Average	Total	Ideal	Present	Future	Gain	Value	Average days	% of season	Value
Outboards	10-20	380	$ 600	$228,000	10	80	100	2.0	$4,560	-	-	-
Inboards	10-20	60	1,200	72,000	10	70	100	3.0	2,160	-	-	-
Cruisers	15-30	90	2,500	225,000	8	60	100	3.2	7,200	8	5.3	$100
Cruisers	31-50	50	8,000	400,000	6	50	100	3.0	12,000	16	10.6	380
Auxiliary sailboats	15-30	12	4,000	48,000	6	50	100	3.0	1,440	8	5.3	30
Sailboats	10-20	8	400	3,200	8	70	95	2.0	60	-	-	-
Totals		600		976,200					27,420			510

Maximum future benefits ($27,420-$510) = $26,910, say $26,900

Equivalent average annual benefits = $26,900

Table 5 - Recreational navigation benefits, boats added because of natural growth

Type of craft	Length, feet	No. of boats	Depreciated value		Percent return					On cruise (150-day season)		
						% of ideal						
			Average	Total	Ideal	Present	Future	Gain	Value	Average days	% of season	Value
Outboards	10-20	155	$ 600	$ 93,000	10	80	100	2.0	$ 1,860	-	-	-
Inboards	10-20	25	1,200	30,000	10	70	100	3.0	900	-	-	-
Cruisers	15-30	35	2,500	87,500	8	60	100	3.2	2,800	8	5.3	$ 40
Cruisers	31-50	15	8,000	120,000	6	50	100	3.0	3,600	16	10.6	110
Auxiliary sailboats	15-30	10	4,000	40,000	6	50	100	3.0	1,200	8	5.3	30
Sailboats	10-20	10	400	4,000	8	70	95	2.0	80	-	-	-
Totals		250		374,500					10,440			180

Maximum future benefits ($10,440 -$180) = $10,260, say $10,300

Equivalent average annual benefits = $10,300

43. BENEFITS, NEW BOATS ADDED AND BOATS TRANSFERRED BECAUSE OF THE IMPROVEMENTS

About 50 new boats are expected to be added because of the improvements, with a total depreciated value of $105,300. Boats expected to be transferred because of the improvement are estimated to number about 150, with a total depreciated value of $243,000. The gain to the new boats added because of the improvement has been assumed to be the total percent return which may be expected when such boats use the improved harbor. The gain to the transferred boats will result from basing these craft closer to the residence of the owner, or at a location more convenient for him or offering better facilities than he has been able to secure elsewhere. The maximum future benefits to the new boats added because of the improvement are estimated at $7,600 annually as shown in table 6. The equivalent average annual benefits are $6,900. Maximum future benefits to transferred boats, and equivalent average annual benefits, are estimated at $5,500 annually as shown in table 7.

Table 6 - Recreational navigation benefits, new boats added because of improvement

Type of craft	Length, feet	No. of boats	Depreciated value Average	Depreciated value Total	Percent return Ideal	% of ideal Present	% of ideal Future	Gain	Value	On cruise (150-day season) Average days	% of season	Value
Outboards	10-20	30	$ 750	$ 22,500	10	0	100	10.0	$2,250	-	-	-
Inboards	10-20	5	1,500	7,500	10	0	100	10.0	750	-	-	-
Cruisers	15-30	8	3,100	24,800	8	0	100	8.0	1,984	8	5.3	$105
Cruisers	31-50	4	10,000	40,000	6	0	100	6.0	2,400	16	10.6	254
Auxiliary sailboats	15-30	2	5,000	10,000	6	0	100	6.0	600	8	5.3	32
Sailboats	10-20	1	500	500	8	0	95	7.6	38	-	-	-
Totals		50		105,300					8,022			391

Maximum future benefits ($8,022 -$391) = $7,631, say $7,600

Equivalent average annual benefits ($7,600 x 0.914) = $6,900

Table 7 - Recreational navigation benefits, boats transferred because of improvement

Type of craft	Length, feet	No. of boats	Depreciated value: Average	Depreciated value: Total	Percent return: Ideal	Percent return: % of ideal: Present	Percent return: % of ideal: Future	Percent return: Gain	Value	On cruise (150-day season): Average days	On cruise (150-day season): % of season	On cruise (150-day season): Value
Outboards	10-20	85	$ 600	$ 51,000	10	70	100	3.0	$1,530	-	-	-
Inboards	10-20	15	1,200	18,000	10	70	100	3.0	540	-	-	-
Cruisers	15-30	20	2,500	50,000	8	70	100	2.4	1,200	8	5.3	$ 64
Cruisers	31-50	10	8,000	80,000	6	70	100	1.8	1,440	16	10.6	153
Auxiliary sailboats	15-30	10	4,000	40,000	6	60	100	2.4	960	8	5.3	51
Sailboats	10-20	10	400	4,000	8	60	95	2.8	112	-	-	-
Totals		150		243,000					5,782			268

Maximum future benefits ($5,782 -$268) = $5,514, say $5,500

Equivalent average annual benefits = $5,500

44. BENEFITS, EQUIVALENT TRANSIENT BOATS

Increased interest in cruising on Lake Michigan indicates that the considered improvement of the harbor would attract an estimated 400 visiting craft annually from harbors along the south and southeast shores of Lake Michigan as shown in table 1. It is estimated that the average stay of these boats would be approximately 5 days each during the boating season, or a total of 2,000 boat-days. Such intermittent use would, therefore, be equivalent to about 14 boats based in the harbor continuously during the 150-day recreational boating season. Table 8 shows the equivalent transient boats by size and type. These transient boats probably visit other harbors now although some additional cruising may be expected when an additional harbor with acceptable facilities becomes available. The benefits to these visiting boats would be similar to those estimated for an equivalent number of transferred boats. The maximum future benefits are estimated in table 8 at $1,400 and equivalent average annual benefits are $1,300.

Table 8 - Recreational navigation benefits, equivalent transient boats

Type of craft	Length, feet	Total prospective transient boats	Equivalent transient boats	Depreciated value		Percent return				
							% of ideal			
				Average	Total	Ideal	Present	Future	Gain	Value
Cruisers	15-30	300	10	$ 3,100	$31,000	8	70	100	2.4	$744
Cruisers	31-50	90	3	10,000	30,000	6	70	100	1.8	540
Auxiliary sailboats	15-30	10	1	5,000	5,000	6	60	100	2.4	120
Totals		400	14		66,000					1,404

Maximum future benefits = $1,404, say $1,400

Equivalent average annual benefits ($1,400 x 0.914) = $1,300

45. BENEFITS, REDUCED DAMAGES

Shallow depths and hazardous conditions at the entrance to New Buffalo Harbor cause damages to the hulls and propellers of boats which use the harbor. Reports of such damages for 1960, which are believed to be representative of probable annual damages without the considered improvements, were obtained from information submitted by boat repair yards and marine insurance firms. Damages and losses reported in 1960 were about $32,000 for local and transient recreational craft. However, that amount includes $9,000 for the total loss of a large cruiser, a loss which cannot reasonably be considered as recurring annually. Available local statistics are insufficient for estimating the frequency of such losses, hence the reported damages of $23,000 for 1960 are accepted as a reasonable approximation of probable annual damages. As shown in table 1, there are 600 present locally based boats. The 240 present transient boats are equivalent to 8 full-time boats (see paragraph 44). Present local full-time boats thus total 608. These boats are expected to be increased by about 41 percent without the improvement (250 boats added locally due to natural growth). Increasing the 1960 damages by that percentage ($23,000 x 1.41) results in $32,400 prospective annual damages and a corresponding project benefit.

46. BENEFITS, REDUCED LOCAL MAINTENANCE COSTS

Local interests estimate that about $16,000 will be required annually for dredging at the harbor entrance to maintain a usable navigation depth during the navigation season. Federal improvement of the harbor would relieve local interests of that obligation, resulting in a corresponding project benefit of $16,000.

47. BENEFITS, INCREASED COMMERCIAL FISH CATCH

The fish catch expected to result from commissioning one new commercial fishing boat at New Buffalo Harbor is estimated in paragraph 21 to average 50 tons annually. Assuming an average value of $360 per ton, based on current values per ton ranging from about $280 for herring to $440 for chub, the increased catch would have a gross value of $18,000. The added expense for the additional catch would include an investment in new equipment. It is estimated, therefore, that the net value of the catch, and the corresponding general project benefit, may reasonably be taken as 25 percent of the gross value, or $4,500 annually.

48. SUMMARY AND ALLOCATION OF BENEFITS

Table 9 summarizes all tangible benefits accruing to the considered improvement. As indicated, total average annual benefits are $104,000, of which 52 percent or $54,000 are general and 48 percent or $50,000 are local. In determining the allocation of benefits it is considered that commercial fishing benefits are general in nature, and that benefits to recreational navigation, reduction in damages to recreational boats, and reduced local maintenance costs are equally general and local in nature.

Table 9 - Summary and allocation of benefits

Benefit	Total	Allocation General	Local
Recreational navigation:			
Present locally based boats	$ 26,900		
Boats added because of natural growth	10,300		
New boats added because of improvement	6,900		
Boats transferred because of improvement	5,500		
Equivalent transient boats	1,300		
Total recreational navigation	50,900	$25,450	$25,450
Reduced damages	32,400	16,200	16,200
Reduced local maintenance cost	16,000	8,000	8,000
Increased commercial fish catch	4,500	4,500	-
Total average annual benefits	103,800	54,150	49,650
(say)	104,000	54,000	50,000
Allocation, percent of total	100	52	48

COMPARISON OF BENEFITS AND COSTS

49. As indicated previously, the estimated average annual charges for the considered plan of improvement are $75,000 and the total average annual benefits are $104,000 resulting in a favorable economic ratio of 1.4 to 1.

PROPOSED LOCAL COOPERATION

50. GENERAL REQUIREMENTS

To assure full public use of the Federal improvement for maximum benefit, local interests should be required to provide an adequate public landing with provisions for the sale of motor fuel, lubricants, and potable water, available to all on equal terms. They should provide and maintain without cost to the United States enough stalls, slips, or mooring facilities, to insure efficient use of the harbor frontage, and should provide police and fire protection for transient and local boats. Local interests should also be required to agree to hold and save the United States free from damages that may result from construction and maintenance of the improvement , and to provide without cost to the United States all lands, easements, and rights-of-way, including beach nourishment stockpile and borrow areas, for the construction and maintenance of the project when and as required. The New Buffalo Port Authority is empowered to regulate the use and development of the harbor facilities with the understanding that such existing and future facilities will be open to all on equal terms. An item of local cooperation in this regard is not required.

51. CASH CONTRIBUTION

As determined in table 9, the benefits to be derived from improvement are 52 percent general and 48 percent local in nature. It is considered that local interests should bear a share of the project cost, exclusive of aids to navigation, commensurate with that portion of benefits that are local in nature. Local interests therefore should be required to make a cash contribution of 48 percent of the actual cost of the general navigation facilities. This cash contribution is presently estimated to be $615,000, based on August 1961 price levels. This estimate is for information only and will be adjusted to actual costs when construction is completed.

52. ASSURANCES

Village and state officials have indicated a willingness to meet the above-proposed requirements of local cooperation. The Michigan State Waterways Commission, on being informed of the general features of the proposed plan of improvement and the required local cooperation, stated that it would provide the cash contribution and would coordinate local efforts to meet other cooperation requirements. It is the opinion of the District Engineer that the responsible authorities are able to meet the proposed requirements of local cooperation, and will do so when and as required.

APPORTIONMENT OF COSTS AMONG INTERESTS

53. Table 10 sets forth the apportionment of first costs and costs of additional maintenance among the Federal agencies and local interests involved. First costs of the general navigation facilities are apportioned between the United States and local interests in accordance with the allocation of benefits made in paragraph 48.

Table 10 - Apportionment of first costs and annual maintenance

Item	Amount
First cost	
Corps of Engineers:	
General navigation facilities	$1,282,000
Preauthorization study cost	15,000
Coast Guard: aids to navigation	5,000
Non-Federal: rights-of-way	21,000
Total project first cost	1,323,000
Maintenance	
Corps of Engineers: channels, beach nourishment stockpile, and breakwaters	21,000
Coast Guard: aids to navigation	500
Total maintenance	21,500
(say)	22,000
Apportioned first cost	
Federal:	
General navigation facilities (52%)	667,000
Preauthorization study cost	15,000
Aids to navigation	5,000
Total Federal first cost	687,000
Non-Federal:	
Cash contribution, general navigation facilities (48%)	615,000
Rights-of-way	21,000
Total non-Federal first cost	636,000
Total first cost	1,323,000

COORDINATION WITH OTHER AGENCIES

54. NON-FEDERAL

The desired improvements described in paragraph 19 have been the subject of discussions, consultations and correspondence, between the District Engineer or his representatives and the designated representative of the Governor of Michigan, representatives of the Michigan State Waterways Commission and the New Buffalo Port Authority, officials of the village of New Buffalo, and local boating interests. In general, all parties concerned concur with the provisions of the proposed plan of improvement. Appendix D contains reproductions of pertinent correspondence with other agencies. In October 1960, local pleasure boat operators and other interested parties at New Buffalo were consulted to obtain latest data on existing and prospective recreational traffic, most recent boating damages, and extent of existing boating hazards.

55. FEDERAL

Federal agencies deemed to have an interest in the matter were requested to review and comment upon the considered plan of improvement. The regional office of the Department of Health, Education, and Welfare advised that the considered improvements would not adversely affect the program of the Public Health Service in the area. The regional director of the United States Fish and Wildlife Service offered an opinion that the improvements would not have a significant effect on fish and wildlife resources if the dredged material is deposited in suitable areas. The United States Coast Guard stated that aids to navigation, including new lights and buoys, would be required as described in paragraph 34.

DISCUSSION

56. GENERAL

There is no active Federal project for improvement of New Buffalo Harbor, which presently comprises the lower two-mile reach of the Galien River. Average width of the natural channel in this reach is 70 feet, depths range up to about 12 feet. Intermittent sandbars at the mouth periodically reduce controlling depths to less than 2 feet in the entrance, leading to hazardous conditions which have caused boating accidents and one recent drowning. Maintenance dredging by local interests has been ineffective in preserving an adequate entrance channel for light-draft vessels. The original Federal project has been inactive since 1885 and no useful portion remains. It is now proposed for abandonment. Local interests request that additional navigation facilities, comprising a new entrance channel with protective structures and an improved inner channel in the river, be provided in the interest of light-draft commercial and recreational navigation.

57. PROSPECTIVE RECREATIONAL TRAFFIC

There has been a rapid growth in the use of New Buffalo Harbor by recreational boats, the approximate number of locally based craft having increased from 30 in 1954 to 600 in 1960. In addition an estimated 240 transient boats visit the harbor during the boating season. It is estimated that, with provision of adequate facilities, the number of locally based boats would reach 1,050 and transient boats 400. A study of the growth of recreational boating in other comparable areas indicates that this anticipated growth is likely to be attained if reasonably good mooring facilities are provided where they can be reached through adequate channels.

58. BENEFITS

Improvement, as shown on the accompanying map, would benefit the present local boat operators by increasing the amount of time that their boats can be used safely. Similar benefits would accrue to future local boat operators, and more transient craft would be encouraged to visit the harbor after provision of better access and berthing facilities. The total of such benefits is estimated to be $50,900 annually. Provision of adequate, protected channels would eliminate present losses caused by damage to hulls and propellers of recreational boats. The resulting annual benefits are estimated at $32,400. Federal improvement of the harbor would relieve local interests of a channel maintenance cost presently estimated at $16,000 annually, resulting in a corresponding project benefit. Commercial traffic is presently limited to an irregular local catch of fish, which is expected to be increased by the proposed improvement of the harbor. The net value of the increased fish catch, and the corresponding project benefit, is estimated at $4,500 annually.

59. ECONOMIC ANALYSIS

The foregoing benefits accruing to the considered improvement total $104,000 annually. Annual costs of the improvement are estimated at $75,000, resulting in a favorable benefit-cost ratio of 1.4 to 1. The annual benefits are determined to be both local and general in nature in the ratio of 48 percent to 52 percent, respectively. An equitable apportionment of the first cost of general navigation facilities would be on that basis, resulting in a non-Federal cash contribution presently estimated at $615,000. The total Federal first cost is estimated at $687,000, and the total non-Federal first cost, including cash contribution and rights-of-way, at $636,000 (August 1961 price levels). As indicated above, the considered improvement is economically justified. It is considered to provide for the principal needs of present and future recreational navigation and commercial fishing, and to provide generally for the desires of local interests regarding improvement for light-draft traffic. Local interests and state officials have reviewed the proposed plan of improvement and have concurred in its features and provisions.

60. SENATE RESOLUTION 148

Additional information on recommended and alternative projects called for by Senate Resolution 148, 85th Congress, 1st session, adopted 28 January 1958, is contained in a supplemental statement to this report.

CONCLUSIONS

61. PROPOSED IMPROVEMENT

New Buffalo Harbor, Michigan, requires improvement by dredging of entrance and inner channels and construction of breakwaters, to provide safe, adequate access to mooring and servicing facilities for pleasure boats and commercial fishing craft in the harbor. This improvement will afford gains in recreational value to owners of local and transient recreational boats, increase the local commercial fish catch, reduce damages to recreational boats, and reduce the cost of channel maintenance to local interests. It is found to be economically justified. The estimated first cost of the improvement, based on August 1961 price levels and with the cost of general navigation facilities apportioned on the same basis as local and general benefits, are $636,000 to local interests and $687,000 to the United States, including $5,000 Federal first cost for required aids to navigation, and $15,000 Federal cost for preauthorization studies. The existing project is completely deteriorated. It has no authorized provisions which would be adaptable to present and future needs, and should be abandoned.

62. FUNDING

It is estimated that one year would be required for advance planning and two years for construction of the improvement, requiring allotments of funds of about $67,000, $300,000 and $300,000 over a period of three successive years. Local interests should comply with the requirements for local cooperation set forth in paragraphs 50 to 52.

RECOMMENDATIONS

63. RECOMMENDED IMPROVEMENT

It is recommended that New Buffalo Harbor, Michigan, be improved in general accordance with the plan of improvement shown on the accompanying map to provide for an entrance channel 10 feet deep, 80 to 180 feet wide, and 850 feet long, to the mouth of the Galien River; new north and south breakwaters having lengths of 1,400 feet and 860 feet respectively; and a deepened inner channel in the Galien River 8 feet deep, 80 feet wide, and 1,250 feet long. The cost to the United States of the recommended improvement is estimated at $667,000 for construction and $21,000 annually for maintenance, both amounts exclusive of aids to navigation.

64. LOCAL COOPERATION

It is further recommended that no work on the project be undertaken until responsible local interests have furnished assurances satisfactory to the Secretary of the Army that they will:

a. Provide without cost to the United States all lands, easements and rights-of-way required for construction and subsequent maintenance of the project and of aids to navigation upon the request of the Chief of Engineers, including suitable areas determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of spoil on a beach nourishment stockpile.

b. Hold and save the United States free from damages due to the construction and maintenance of the project.

c. Provide and maintain without cost to the United States necessary mooring facilities and utilities including a public landing with suitable supply facilities open to all on equal terms, the dredging of berthing areas to be commensurate with the depth of the Federal channel improvements.

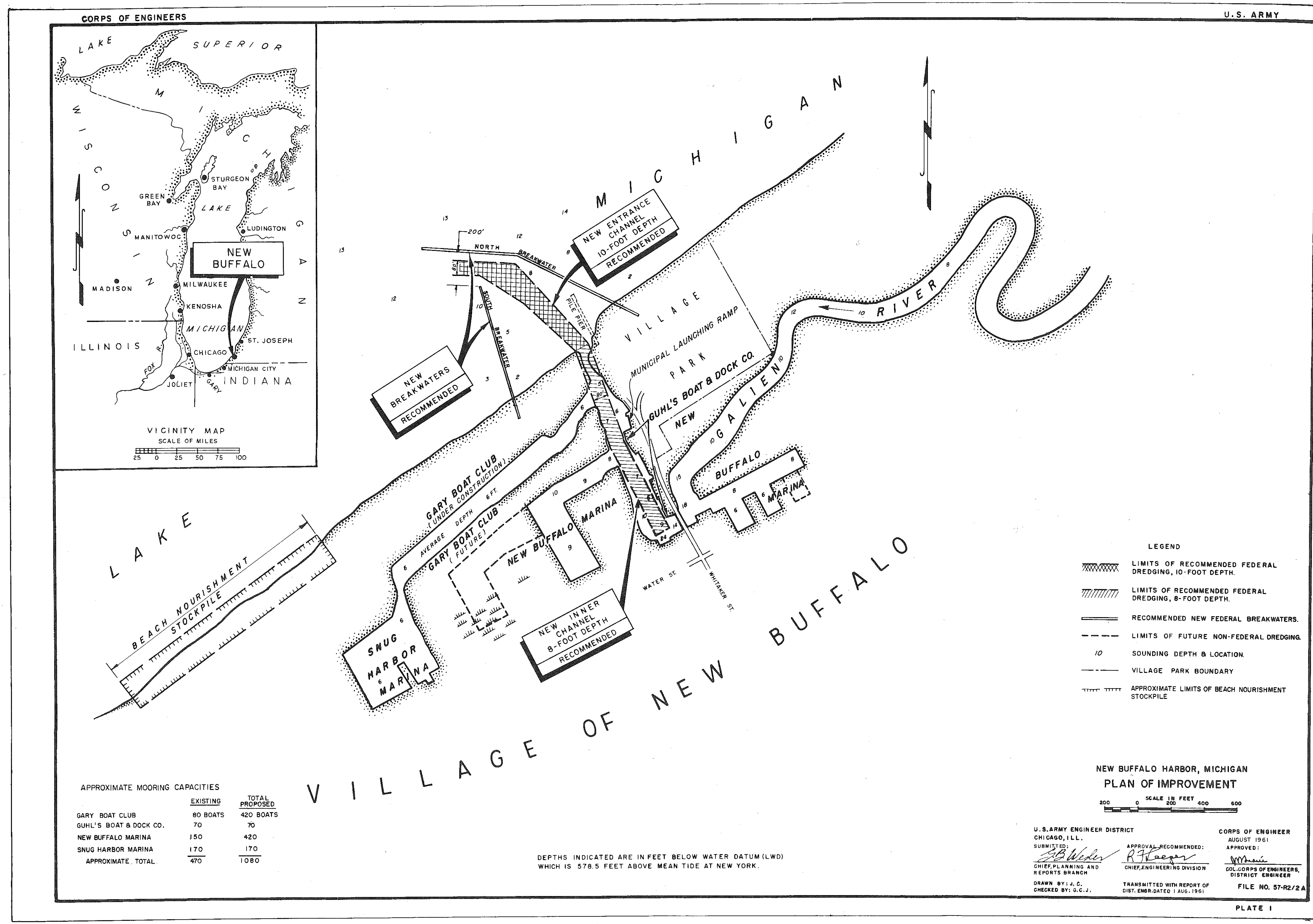
d. Reserve mooring facilities adequate for the accommodation of transient craft.

e. Make a cash contribution of 48 percent of the actual first cost of the general navigation facilities, comprising the breakwaters, entrance channel, and inner channel. The local cash contribution is presently estimated (August 1961 price levels) at $615,000.

65. RECOMMENDED ABANDONMENT

It is also recommended that the original project for improvement of New Buffalo Harbor, adopted in 1857, be abandoned.

J. A. SMEDILE
Colonel, Corps of Engineers
District Engineer



APPROXIMATE MOORING CAPACITIES

	EXISTING	TOTAL PROPOSED
GARY BOAT CLUB	80 BOATS	420 BOATS
GUHL'S BOAT & DOCK CO.	70	70
NEW BUFFALO MARINA	150	420
SNUG HARBOR MARINA	170	170
APPROXIMATE TOTAL	470	1080

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX A - HYDRAULIC ANALYSIS FOR BREAKWATER DESIGN

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U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX A - HYDRAULIC ANALYSIS FOR BREAKWATER DESIGN

1. INTRODUCTION

This appendix contains an engineering analysis for location of breakwaters, entrance and spending beach for the proposed harbor of refuge at New Buffalo, Michigan. The analysis is based on navigation factors, wave action, refraction, diffraction and reflection. Since the harbor entrance admits wave energy as well as boats, adequate protection from wave action must be obtained without impairing the safe and easy ingress and egress of boats. The above factors are evaluated for conditions at the site, after which optimum locations of breakwaters, entrance, and spending beaches are determined. In addition to the above factors, the locations of the entrance and breakwaters depend also on the direction and magnitude of littoral drift. Appendix C covers the littoral drift problem at the proposed harbor with reference to these factors and probable shoreline changes.

2. House Document No. 446, 78th Congress, 2d session considered an arrowhead-type harbor at New Buffalo, with a sheltered area of about 10 acres enclosed by 1,250 feet of breakwaters. The entrance, 170 feet wide, was to face northeast. The considered harbor was protected from wave action in the northwest quadrant. The northerly and southerly portions of the harbor were to be dredged to depths of 12 and 8 feet respectively.

3. GEOGRAPHICAL DESCRIPTION

New Buffalo Harbor is located at the mouth of Galien River on the southeast shore of Lake Michigan, about 10 miles northeasterly of Michigan City, Indiana and 25 miles southwesterly of St. Joseph, Michigan. The harbor is exposed to waves from both the northwest and northeast quadrants. The maximum fetch of 285 miles extends to the vicinity of Pt. Au Barques, Michigan and bears about N. 3° E. The shoreline in the vicinity has a direction of about N. 50° E.

4. The Galien River discharges into the harbor. The river has a length of about 30 miles and drains about 180 square miles. Before entering the lake, the lower portion of the river meanders through a marsh known as

Lake Pottawatomie. This portion of the river has a slope of only 0.7 foot per mile. The marsh is generally dry at ordinary stages of the lake, but is flooded during high water periods or during freshets of the Galien River. This inland basin is separated from the lake by a series of sand dunes through which was cut the present channel of the river. At one time the river outlet was about a half mile southwest of its present location. Continuous gaging records for this stream are not available. A maximum discharge of 3,500 c.f.s. is estimated to have occurred in April 1947 below the New Troy Mill dam, 20 miles from the mouth, where the watershed area is 81 square miles. Considerable silting has occurred below this dam after floods. Soil erosion is in progress in the upper reaches, and farmers have reported that deposits of sand have ruined crops after floods. The rate of sediment transport are unknown. The mean average rainfall is about 35 inches over the basin.

5. Lake frontage along New Buffalo Township, Michigan extends for about 8 miles, terminated on the south by the Michigan-Indiana state line. The Galien River enters the lake about 5 miles northeast of the state line. Good sand beaches extend along the frontage northeast of the river. Southwest of the river a belt of sand dunes borders the lake front and has been developed for residential use. Erosion is in progress here and expensive bulkheads have been constructed by private interests to protect property in this area.

6. WIND CONDITIONS

The nearest U.S. Weather Bureau stations to New Buffalo, with recorded wind data, are at Grand Haven, Michigan, 90 miles north and at Chicago, Illinois, 45 miles to the west. A wind rose for eight directions for the Chicago station at Navy Pier, for the 15-year period January 1932 to December 1946, is shown on plate A-1. The diagram shows that wind velocities of 10 to 15 m.p.h. were most frequent, and occurred about 40 percent of the time. Wind velocities higher than 25 miles per hour averaged about 10 days per year during the period and were usually from the south or north.

7. A wind rose for eight directions for Grand Haven, Michigan for the period January 1921 to June 1933, is also shown on plate A-1. The diagram shows that winds of greatest average intensity blow from south through west to northwest about 60 percent of the time. Less intense winds blow from north through east to southeast the remainder of the time. High velocity winds are comparatively rare.

8. The harbor is exposed to wave action generated by winds ranging from W through N to NNE. The wind rose at Chicago shows that these winds comprise about 51 percent of the total wind movement, while at Grand Haven they comprise about 54 percent.

9. STORM RECORDS

Table A-1 shows data recorded at Navy Pier, Chicago, for the most severe storms on the south end of the lake during the period 1929-1951. The table also shows the temporary increase in water levels as recorded at Calumet Harbor due to wind action. The average velocity of sustained wind for this group of severe storms was 31 miles per hour.

Table A-1 - Storms, south end of Lake Michigan (1929 - 1951)

Date of storm	Wind data: Average sustained wind, MPH	No. of hours sustained	Max. wind for 5-Min. period, MPH	Direction of wind	Corresponding still water lake levels at Calumet Harbor (1): Before storm, feet	After storm, feet	Max. during storm, feet
21-23 Oct 1929	37	49	70	NNW	+2.8	+2.5	+6.7
17-18 Dec 1929	35	49	52	NE N NW	+2.4	+2.5	+4.1
7-8 Mar 1930	33	34	45	N	+2.3	+2.2	+3.5
7-10 Mar 1931	31	80	48	N	+0.9	+0.9	+1.8
10-11 June 1936	25	40	104	N	+1.1	+1.3	+1.9
6- 9 Apr 1938	31	100	48	NE	+1.1	+1.3	+2.7
6- 7 Nov 1941	27	42	45	NNE	+0.6	+0.5	+1.9
6- 8 Feb 1942	33	51	42	N	+0.4	+0.5	+1.7
20-22 Nov 1942	25	50	33	N	+0.8	+1.0	+2.5
28-29 Sept 1945	27	31	51	NNE	+2.4	+2.6	+4.1
26-27 Mar 1948	36	29	52	N	+1.6	+1.5	+3.8
29-30 Dec 1948	34	33	50	N	+0.5	+0.6	+2.9
25-26 Nov 1950	30	40	42	NW	+0.8	+0.9	+3.2

(1) Lake levels have reference to low water datum for Lake Michigan, which is 578.5 feet above mean tide at New York.

10. Examination of the wind rose for Chicago shows that 25- to 30-mile per hour winds comprise the group of higher velocity winds having appreciable durations. According to the Bretschneider, revised Sverdrup-Munk technique for wave forecasting used in this appendix, appreciable wind durations are required for maximum wave formation. Table A-1 indicates an average storm wind velocity of 31 miles per hour; therefore, a 30-mile per hour wind was used for wave forecasts in the refraction diagrams.

11. LAKE LEVELS

The average elevation of the lake varies irregularly from year to year. Continuous records of lake levels since 1860 are available. The average stage for the period 1860-1952 was 580.57 feet (above mean tide at New York). The highest one-month average of 583.68 feet occurred in June 1886 and the lowest of 577.35 feet occurred in February 1926. Since the average stage is 2.07 feet above low water datum elevation of 578.5, the lake was assumed at +2.0 for refraction and diffraction diagrams.

12. The elevation of Lake Michigan to be used for design of structures should be the maximum elevation that can be anticipated to occur with a reasonable frequency. Such a design elevation is considered to be the maximum monthly average stage that may be expected to occur once each 20 years together with a temporary rise, of expected frequency of occurrence of once each year, superimposed upon it. For the period 1900-1953, the maximum monthly average elevation of the lake recurring with a frequency of once in 20 years is 582.00 feet. A temporary rise of 1.85 feet which occurs at Calumet Harbor once each year is assumed to apply at New Buffalo. (Ref. Technical Memorandum No. 36 Beach Erosion Board.) The design lake elevation is then 583.85 feet, or 5.35 feet above low water datum.

13. WAVES

A wave rose for an average annual full year was drawn for New Buffalo using statistical data in the hindcast study conducted by the Beach Erosion Board (Technical Memorandum No. 36). It was assumed that the durations of waves from N and NNE at Chicago and the durations of waves from W, WNW, NW and NNW at Muskegon were applicable at New Buffalo. The wave rose is shown in plate A-1. Wave heights given are significant wave heights in deep water and include periods from 1 to 7 seconds.

14. EXISTING IMPROVEMENTS

A project of improvement was adopted in 1857 and provided for a revetted entrance channel 200 feet wide and 12 feet deep cut through the sand dunes between Lake Michigan and Lake Pottawatomie. By 1872 the entrance channel had been cut through three times but was immediately closed again by sand from the lake. A pile pier 300 feet long was constructed along the north side of the entrance and was extended 100 feet in 1885. The south pier is believed to have been built by local interests. Two parallel entrance piers 160 to 260 feet long in poor condition still remain. These are rows of 2" x 12" wood sheeting braced by 12" round wooden piles on 6-foot centers. The entrance is heavily shoaled. Extensive small-boat mooring facilities are being constructed upstream from the mouth by local interests.

15. CONSIDERED IMPROVEMENTS

The locations of entrance breakwaters, and spending beach determined in this appendix are that shown on the drawing which accompanies the main report. The new north and south breakwaters are located to converge westward towards the entrance in the form of an arrowhead. This arrangement forms a large, protected harbor area and allows for the dispersal of wave energy, admitted through the entrance, by diffraction and reflection. The existing flat lake beach north of the Galien River mouth will be retained to serve as a wave absorber, or spending beach. Westerly waves admitted through the entrance will break some distance from the spending beach and dissipate their energies in the breaker zone. The entrance faces west and is located about 800 feet northwesterly from the mouth of the Galien River. The proposed entrance is 200 feet wide which is considered an adequate, safe width for small-boat navigation.

16. The outer breakwater is located in about 12 feet of water at the entrance which is adequate for small-boat navigation. This location and the arrowhead arrangement serve to furnish an enclosed area of about 8 acres which is adequate for the harbor of refuge purpose.

17. A parallel pier arrangement was considered but rejected because adequate wave energy dispersal area and spending beach could not be provided. For breakwater lengths comparable to the adopted plan, the parallel pier arrangement provides less sheltered area for boats seeking refuge from storms.

18. A harbor with entrance facing northeast was considered but also rejected. However, the direction of the predominant littoral drift is from the northeast and the entrance is not shielded from this drift. Therefore, more material would be trapped by it and would require more maintenance dredging and would cause greater erosion of the southerly shoreline than for the adopted plan.

19. LITTORAL DRIFT AND SHORELINE CHANGES

The littoral drift problem at the harbor is covered in detail in appendix C.

20. WAVE REFRACTION

When waves move shoreward from deep water and approach the shoreline at an angle, the wave crests are bent because the inshore portion of the wave travels at a lower velocity than the portion in deep water, consequently the crests tend to conform to the bottom contours. This phenomenon is called refraction. As the waves approach shallow water their period remains constant but their height, length and orientation vary. These changes begin to occur when the wave begins to "feel bottom" in depths of about half the wave length. It is assumed that no energy flows laterally along a wave crest between adjacent orthogonals. These facts are utilized in preparing the refraction diagrams by the graphical method used in this appendix.

21. The wave refraction diagrams were made to determine how, and to what degree, deep water waves are modified as they approach the shoreward areas and breakwaters. The directions of refracted waves at the harbor indicate those orientations of entrance and breakwaters which will reduce direct wave energy in the harbor, insofar as possible, while still providing for navigation requirements. The refraction diagrams are also used to calculate refraction coefficients which are used to obtain shallow-water wave heights.

22. DIRECTION OF WAVES

The inshore directions of waves depend on the underwater contours which are generally parallel to the shoreline. There are no unusual hydrographic features. The shoreline for 4 miles on each side of the proposed harbor is generally straight and bears about N 50° E. Since waves approaching normal to the shoreline are refracted the least, deep-water waves from N 40° W are not refracted as much as those approaching from either side of this direction.

23. The direction of deep-water waves having significant action at the harbor range from W through N to NNE, an action zone of 112-1/2°. Waves from outside this action zone are possible but are of the local chop-type with small amplitudes because of short fetches and shallow depths. The limiting wave directions are determined by the shape of Lake Michigan and the proposed harbor location. The most severe wave action at the harbor is generated by strong northerly winds and gales, since they act over the longest fetches of the lake.

24. WAVE FORECASTING

The deep-water wave forecasting technique (Bretschneider, revised Sverdrup-Munk) as described in Technical Report No. 4 of the Beach Erosion Board was used. This technique relates the wave height and period to fetch length, wind velocity and wind duration. Fetch lengths and wind velocity control the maximum wave heights developed, assuming that duration is adequate. Thus for known fetches, wind directions and a 30-mile per hour wind velocity (see par. 10) the corresponding wave heights and periods were determined. Table A-2 shows characteristics of the forecasted waves. For all wave directions except west the fetch depths exceed one-half the wave length and waves are considered the deep-water type. The table shows significant wave characteristics. The significant wave height is the average of the highest one-third of the waves in a wave train. In such trains the average height of the highest 10 percent exceeds the significant wave height by 27 percent. For fetches in the open sea, the maximum wave height depends on wind velocity and duration, whereas for limited bodies of water, such as Lake Michigan, the maximum wave height is usually determined by the wind velocity and fetch. The significant wave height is used for design.

Table A-2 - Deep-water wave forecasts for 30 mile per hour winds

Direction of wave	Fetch, miles	Max. depth along fetch, feet	Min. wind duration, hours	Wave: Height in feet, H_o	Wave: Period in seconds, T_o	Wave: Length $L_o = 5.12T_o^2$, feet
N17°30'E	86	186	9.4	8.3	7.5	288
N3°00'E	285(Max.)	636	22.0	12.0	10.2	533
N2°30'W	237	726	18.3	11.4	9.8	492
N16°00'W	166	504	14.0	10.3	9.0	415
N38°00'W	84	396	8.2	8.2	7.5	288
N57°00'W	67	204	7.0	7.5	7.0	251
N71°00'W	51	174	5.7	6.8	6.5	216
West	43	78	4.9	6.4	6.2	197

25. PROCEDURE

The refraction diagrams were drawn by the method described in Technical Memorandum No. 4 of the Beach Erosion Board. The general contour pattern in the harbor approaches from all lakeward directions was developed in two maps. One map showing underwater contours from 45 to 150 feet at 5-foot intervals in the harbor vicinity was prepared to a scale of 1 inch equals 5,000 feet, from data on U. S. Lake Survey Chart No. 75 with scale 1:120,000. A second map was then prepared to a scale of 1 inch equal to 500 feet, with contours from shore to 45-foot depth at 3-foot intervals, using data on U. S. Lake Survey charts with scale 1:40,000. At the 150-foot depth refraction changes for all waves considered were negligible. Minor irregularities in the natural contours have been smoothed out for use of these maps.

26. A fan diagram was then prepared to show how orthogonals, emanating from the breakwater head, would be changed in direction when carried into deep water. Seven refracted wave directions ranging from N 10° W to N 70° W inclusive, at 10° intervals were used. The orthogonals were determined by a trial-and-error procedure. Trial orthogonals were projected into deep water using assumed periods, the fetches were measured and the actual periods found by forecasts as described in par. 24. The trials were continued until the assumed and actual periods corresponded. It was found that orthogonals for 30-mile per hour winds could not be drawn using refracted directions outside the zone from N 10° W to N 70° W. This shows that the significant refracted wave action for 30-mile per hour winds occurs in this 60° zone.

27. Seven refraction diagrams were then prepared for the deep-water directions determined by the individual orthogonals in the fan diagram. Companion orthogonals were projected shoreward to the 15-foot depth on both sides of those projected lakeward in order to find the relative distance between orthogonals in deep and shallow water. To facilitate the transfer of orthogonals from plate A-1 to plate A-2 and for calculating refraction coefficients, the distances between orthogonals on the former are taken as one-tenth those actually shown. This causes little error since most of the refraction occurs in depths less than 45 feet. With the lake at +2.0 L.W.D. (see par. 11), the computed constants used in preparing refraction diagram No. 5, for example, are shown in table A-3. For projecting orthogonals lakeward or shoreward the respective values of $\frac{C_s}{C_d}$ or $\frac{C_d}{C_s}$ are used between the contours.

The refraction diagrams are shown on plates A-1 and A-2.

Table A-3 - Computations for orthogonals in refraction diagram No. 5. T=7.0 seconds, L_o=251 feet.

Depth of water, d, feet.	$\frac{d}{L_o}$	$\frac{C}{C_o}$ = tanh $\frac{2\pi d}{L}$	$\frac{C_d}{C_s}$ (1)	$\frac{C_s}{C_d}$ (1)
14	.0558	.5573		
			1.09	.92
17	.0677	.6058		
			1.07	.93
20	.0797	.6484		
			1.06	.94
23	.0916	.6856		
			1.05	.95
26	.104	.7200		
			1.04	.96
29	.116	.7497		
			1.03	.97
32	.127	.7742		
			1.03	.97
35	.139	.7983		
			1.03	.97
38	.151	.8200		
			1.02	.98
41	.163	.8396		
			1.02	.98
44	.175	.8572		
			1.02	.98
47	.187	.8731		
			1.03	.97
52	.207	.8960		
			1.02	.98
57	.227	.9152		
			1.02	.98
62	.247	.9311		
			1.01	.99
67	.267	.9443		
			1.01	.99
72	.287	.9552		
			1.01	.99
77	.307	.9641		
			1.01	.99
82	.327	.9713		
			1.01	.99
87	.347	.9772		
			1.00	1.00
92	.366	.9817		

(1) C_d= wave speed at deeper contour
C_d= wave speed at shallower contour

28. REFRACTION COEFFICIENTS

The refraction coefficient, K, is given by $K^2 = \frac{b_o}{b}$, where b_o is the length of wave crest between adjacent orthogonals in deep water and b is the corresponding length at the 15-foot depth. The refracted and deep-water wave directions and coefficients are summarized in table A-4. Waves with refracted direction N 40° W are refracted least since they approach nearly normal to the shoreline. Refraction effects increase for waves approaching from either side of this direction. The coefficients are used in calculations for shallow-water wave heights.

Table A-4 - Refraction coefficients at 15-foot contour

Wave direction		Refraction coefficient, K
Refracted	Deep water	
N10°W	N17°30'E	.56
(1)N17°15'W	N3°00'E	.61
N20°W	N2°30'W	.63
N30°W	N16°00'W	.80
N40°W	N38°00'W	.88
N50°W	N57°00W	.62
N60°W	N71°00'W	.59
N70°W	West	.64

(1)Estimated for maximum fetch direction

29. LOCATION OF ENTRANCE AND BREAKWATERS

The directions of deep-water waves extend from W through N to N 17°30'E, a zone of 107°30'. Refraction contracts this reach into a 60° zone ranging from N 70° W to N10° W, or about 56% of the deep-water zone.

30. The refracted wave zone shows that an entrance facing northeast provides maximum wave protection. However, this location is excluded because of the large amount of littoral material moving southwesterly. Entrances facing west, northwest, and southwest were considered with respect to the refracted wave action zone and navigation requirements. The best centerline alinement for the inner navigation channel is approximately along the center of the river channel, and for the entrance channel about N 45° W to the arrowhead. From the arrowhead to deep water, through the entrance, an east-west channel alinement provides a turning angle of 45° at the arrowhead which is suitable for small boat navigation. The entrance then faces west, and the outer reach of the

north breakwater has an east-west alinement. This plan excludes most of the refracted wave action, has a reasonable breakwater length and provides adequate navigation conditions. An alinement of the outer reach of breakwater between east-west and north-west improves navigation conditions but the breakwater length must be increased to shield the northwest entrance from refracted waves. A south-west alinement for the outer reach of breakwater gives excellent shielding to a southwest entrance but less desirable navigation conditions, since boats are denied direct movements to and from deep water. Locations of the west entrance and the east-west reach of breakwater are a compromise and were chosen for further anlaysis of the degree of protection provided.

31. The south breakwater was terminated at the 8-foot contour which determines its length. The lakeward end was located 100 feet from the east-west channel centerline.

32. The east-west reach of the north breakwater is fixed by the 200-foot wide entrance opening and location of the lake end of the south breakwater. The optimum length was determined by diffraction analysis. The landward ends of the breakwaters are about 800 feet apart at the shoreline.

33. SPENDING BEACH

Changes in waves of small amplitude and period due to refraction are small. These waves, coming from the west, will be admitted directly. For this reason the north breakwater has an alinement of N 65° W, which permits the reflection of waves from it and onto a spending beach where their energy will be dissipated. The existing 300-foot beach will be retained for this purpose. Diagram No. A-9 on plate A-4 shows the spending beach and breakwater orientation required to provide 25° incident and reflected angles for west waves.

34. WAVE DIFFRACTION

Wave diffraction results when waves are propagated into a sheltered region formed by breakwaters that interrupt a portion of the regular wave trains. The two general cases in practice are the passage of waves around the end of a breakwater and the passage of waves through a breakwater gap. Both cases are applied in this analysis. The diffraction diagrams were drawn with the use of the generalized diagrams for gaps and table E-1 in Technical Report No. 4 of the Beach Erosion Board.

35. PURPOSE

Diffraction diagrams were drawn to determine the degree of protection, as measured by diffracted wave heights in the harbor, against the various storms considered. They assist in finding the length of the north breakwater required to hold these heights to reasonable values. A range of 0.5-2.0 feet for these values as considered reasonable.

36. BASIC DATA

The wave data used for preparing the diffraction diagrams shown on plates A-3 and A-4 are shown in table A-5. In the table, the stillwater depth, d, is 17 feet. The values of L_o and H_o are given in table A-2. The values of $\frac{d}{L}$ and $\frac{H}{H_o'}$ are given in "Tables of Gravity Wave Functions" by R. I. Weigel. The ratio $\frac{H}{H_o'}$ is the shoaling coefficient. The wave height at entrance, $H = K \frac{H}{H_o'} H_o'$, where K is the refraction coefficient given in table A-4.

Table A-5 - Wave data for diffraction diagrams

Wave direction Deep-water	Refracted	$\frac{d}{L_o}$	$\frac{d}{L}$	$\frac{H}{H_o'}$	H feet	L feet
N17°30'E	N10°W	.0590	.1033	.9958	4.6	164
N2°30'W	N20°W	.0346	.07701	1.094	7.8	221
N16°00'W	N30°W	.0410	.08842	1.059	8.7	201
N38°00'W	N40°W	.0590	.1033	.9958	7.3	164
(1)N47°30'W	N45°W	.0633	.1075	.9858	5.9	158
N57°00'W	N50°W	.0677	.1117	.9758	4.5	152
N71°00'W	N60°W	.0787	.1220	.9566	3.8	139
West	N70°W	.0863	.1289	.9465	3.9	132

(1)Estimated

37. EAST-WEST REACH OF NORTH BREAKWATER

With the entrance and location and direction of all breakwaters established (see pars. 29-33), studies were made to find the length of east-west reach of north breakwater required to hold diffracted wave heights in the harbor to about 2 feet.

38. An initial length of 420 feet was used for analysis. This results when the geometric shadow for refracted waves of N 45° W passes through the ends of the north and south breakwaters, which excludes 35° of the direct waves in the 60° refracted wave zone

or about 58% (see diagram No. 5, plate A-3). The results of the analysis for a 420-foot length are shown in diagrams Nos. 1-8 on plate A-3. Diagrams Nos. 1-5, inclusive, show diffraction from the east-west reach of breakwater. Diagrams Nos. 6-8 show conditions when direct waves enter through the "imaginary gap". The diagrams show the diffraction coefficients, K', which denote waves of equal diffracted wave heights. The diffracted wave height is equal to the product of the height of waves at entrance (see table A-5) and the diffraction coefficient. Table A-6 shows maximum diffracted wave heights in the harbor for 30-mile per hour winds and a length of 420 feet.

Table A-6 - Maximum wave heights for wind velocity 30 m.p.h.

	Length of east-west reach of north breakwater			
	420 feet		580 feet	
Direction of refracted wave	Max. wave heights, feet	Percent of harbor area in which wave height exceeds 2.0 feet	Max. wave heights, feet	Percent of harbor area in which wave height exceeds 2.0 feet
N10°W	0.7	not applicable	0.5	not applicable
N20°W	1.6	" "	1.2	" "
N30°W	2.6	" "	1.3	" "
N40°W	2.2	" "	1.5	" "
N45°W	2.4	" "	1.2	" "
N50°W	3.2	7.0	1.7	" "
N60°W	2.3	6.9	2.3	" "
N70°W	3.5	29.8	2.7	6.8

Wave heights exceed 2 feet for all waves except those from N 10° to 20° W. For deep-water waves from the west 29.8% of the harbor area has wave heights over 2 feet. These conditions are excessive for small boat navigation.

39. To reduce wave heights, the length was increased. A length of 770 feet would exclude all direct waves in the 60° refracted wave zone but has excessive cost. A compromise length of 580 feet was selected which results when the width of the "imaginary gap" of 120 feet in diagram No. 8 is reduced to a value of one-half the wave length, or 66 feet. Diagrams Nos. 1A-8A on plate A-4 show conditions for the 580-foot length. The diffraction diagram for the north breakwater cannot be used directly for diagrams Nos. 6A and 7A since the angle between breakwater and wave approach is less than 45°. Values of K' used were interpolated between the diagram values and K'=1.0 for wave crests approaching normal to the

breakwater. Table A-6 shows the maximum diffracted wave heights in the harbor for 30-mile per hour winds, and a length of 580 feet. Waves exceeding 2.0 feet still exist for the N 60°-70° W directions, but occupy only 6.8% of the harbor area when admitted through the gap. These conditions provide adequate protection without excessive cost. Extensions in length beyond 580 feet result in maximum costs per unit foot of breakwater since deep water is encountered. Only slightly more protection is achieved, therefore, the 580-foot length was selected.

40. WEST WAVES

Deep-water waves from the west are critical for the proposed plans. These waves, when generated by 30 m.p.h. winds, are refracted to N 70° W at the entrance (see table A-5). Lower wind velocities were considered which generate waves of lower periods with less refraction, and so more wave energy enters through the gaps. Table A-7 shows percent of harbor area in which wave heights exceed 2 feet for west winds. West waves of 3 second period and less have negligible refraction. Wave heights over 2 feet in the harbor do not increase significantly for lower period waves.

Table A-7 - Wave heights exceeding 2 feet for west winds

Wind velocity, m.p.h.	Deep-water wave H_0, ft.	T_0, sec.	Refraction Coefficient, K(1)	Wave(1)	Wave at entrance H, feet	L, feet	Gap opening, feet	Percent of harbor area in which wave heights exceed 2.0 feet
30	6.4	6.2	.64	N70°00'W	3.9	132	66	6.8
24	4.9	5.6	.71	N73°45'W	3.2	116	91	7.5
18	3.5	4.8	.80	N78°45'W	2.6	95	126	7.0
14	2.5	4.2	.86	N82°30'W	2.0	79	151	7.5

(1) Estimated for 24, 18, and 14 m.p.h. assuming no refraction at T_0=3 sec.

41. EVALUATION OF PROPOSED HARBOR

The deep-water waves from W to WNW which give rise to wave heights exceeding 2 feet in the harbor comprise about 12% of the total annual wave action. They occur about 5% of the total time. Thus the plan provides a high degree of protection.

42. The above analysis does not consider waves generated in the harbor when the breakwaters are overtopped. The magnitude of such waves cannot be predicted readily by analytical methods.

43. The waves entering through the gaps will be reflected and absorbed by the north rubble-mound breakwater and spending beach. Model tests made by the Waterways Experiment Station indicate that a breakwater with 1 on 1.5 slope will absorb about 54% of the wave energy. The remaining reflected energy will be completely absorbed by the spending beach. The transmission of wave energy to the interior marina areas will be insignificant.

44. The rubble-mound structures will also act as wave absorbers and materially reduce the reflection of waves during storms, and will thereby materially benefit navigation. It has been shown that waves reflected by structures may produce crossed wave patterns and may combine with incidental storm waves to increase wave heights as much as 100 percent thereby seriously affecting navigation. The reflective effects are most pronounced when vertical wall structures are used.

45. The north breakwater will shield the entrance from the heavy littoral drift moving southwestward and the location of the south breakwater head in 8-foot depth will decrease maintenance dredging.

46. RUBBLE-MOUND BREAKWATERS

Stable slopes and weights of stone for rubble-mound breakwaters were determined by Hudson's breakwater stability formula for non-breaking waves (Ref. Research Report No. 2-2, Waterways Experiment Station, July 1938). The no-damage, no-overtopping condition was used with a damage coefficient of 3.2. Stone weighing 150 lbs. per cubic foot (specific gravity 2.4) was assumed. The lake stage was assumed at 583.85 feet L.W.D. (see par. 12). The crown was assumed at +7.0 L.W.D. Since the structures are located in shallow water it is probable that waves will break on them. The maximum wave used is the highest that can exist up to the breaking point in a 12-foot depth contour, or 13.3 feet. For a lakeside slope of 1 on 1.5, stones should weigh about 13 tons. A crown width of about 2 stone thicknesses or 12 feet was selected. The harborside slope is also 1 on 1.5.

47. The rubble-mound sections for the Indiana Harbor breakwater were built of stone ranging from 8 to 20 tons weight, or an effective weight of 13 tons for stability of the cap stones. The lakeside slope is 1 on 2 and the design wave height is estimated at 15 feet. Since construction, repairs to this structure have been nominal, therefore use of comparable criteria at New Buffalo seems reasonable.

48. CONCLUSIONS

The breakwaters and entrance provide maximum protection against the 60° zone of refracted wave action, while still satisfying navigation requirements, and shielding the entrance against the heavy littoral drift moving southwesterly. The proposed plan provides an adequate basis for developing a project.

49. Additional conclusions are:

a. The entrance should face west because of the littoral drift.

b. The breakwaters should be rubble-mound type to reduce the reflection of waves into navigation areas.

c. For deep-water waves from N 57° W, through N to N 17° 30'E generated by sustained winds of 30 m.p.h., the maximum wave height in the harbor is 1.7 feet.

d. For deep-water waves from W to N 71° W, generated by winds of 30 m.p.h. and less, the wave heights in the harbor exceeding 2 feet occur over a maximum of 7.5% of the harbor area near the entrance, but this happens not more than 5 percent of the time.

e. A spending beach should be reserved on the north side of the harbor to absorb wave energy.

f. Wave energy admitted to the interior marina areas is insignificant.

g. Cap stone for breakwaters should average 13 tons weight and be laid on 1 on 1.5 slopes on both sides.

h. A parallel pier type of lake entrance is not recommended.

50. HYDRAULIC MODEL STUDY

Since complex hydraulic phenomena will exist in the proposed harbor such as waves caused by overtopping, double diffraction from breakwater heads and reflection which cannot be readily solved by analytical or graphical methods, a model investigation should be made prior to preparation of final plans for the proposed improvement. This investigation would extend the scope of this study to determine the optimum arrangement of all structures in the interests of safety to navigation and economy of construction.

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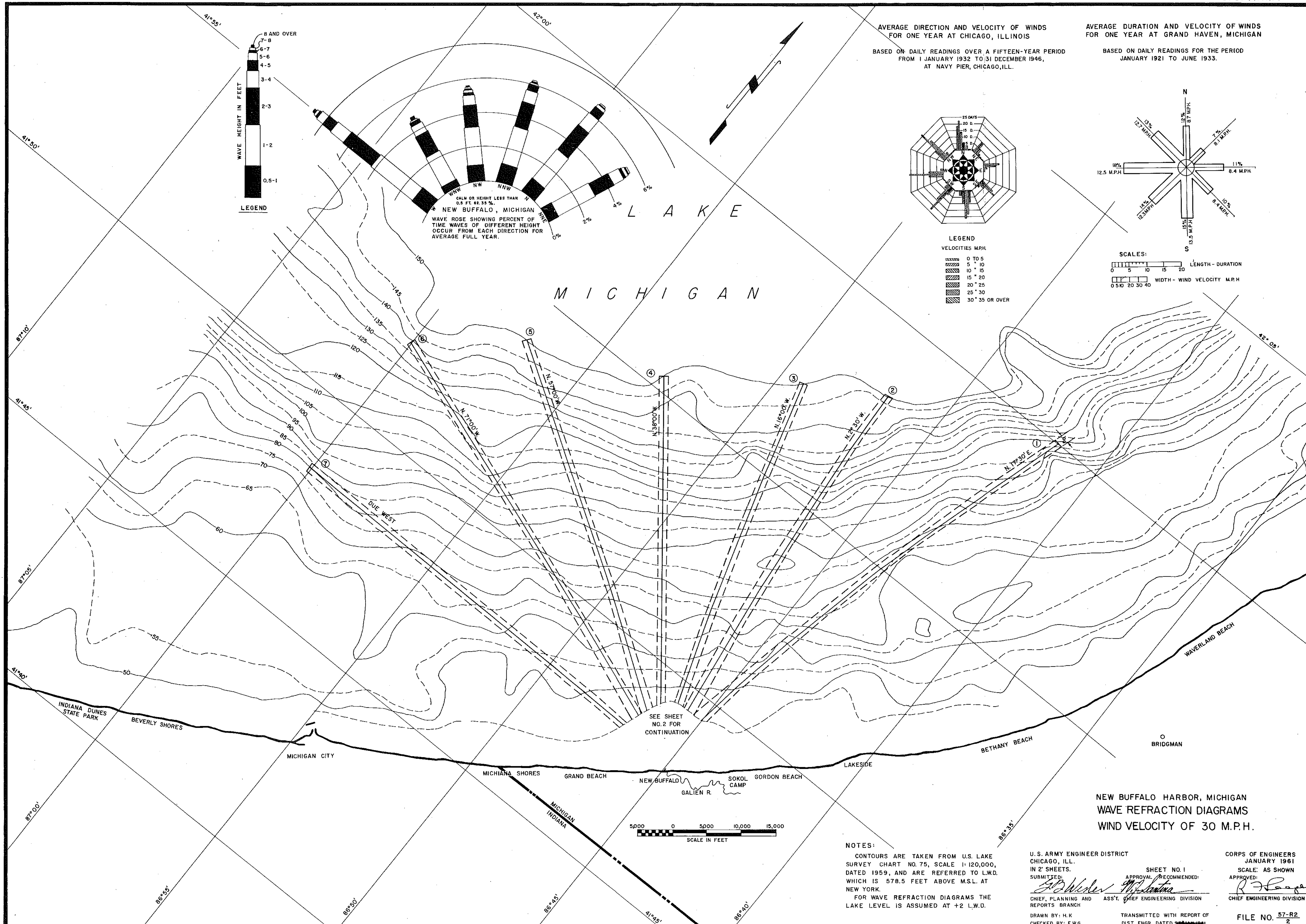

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APPENDIX A, PLATE A-1

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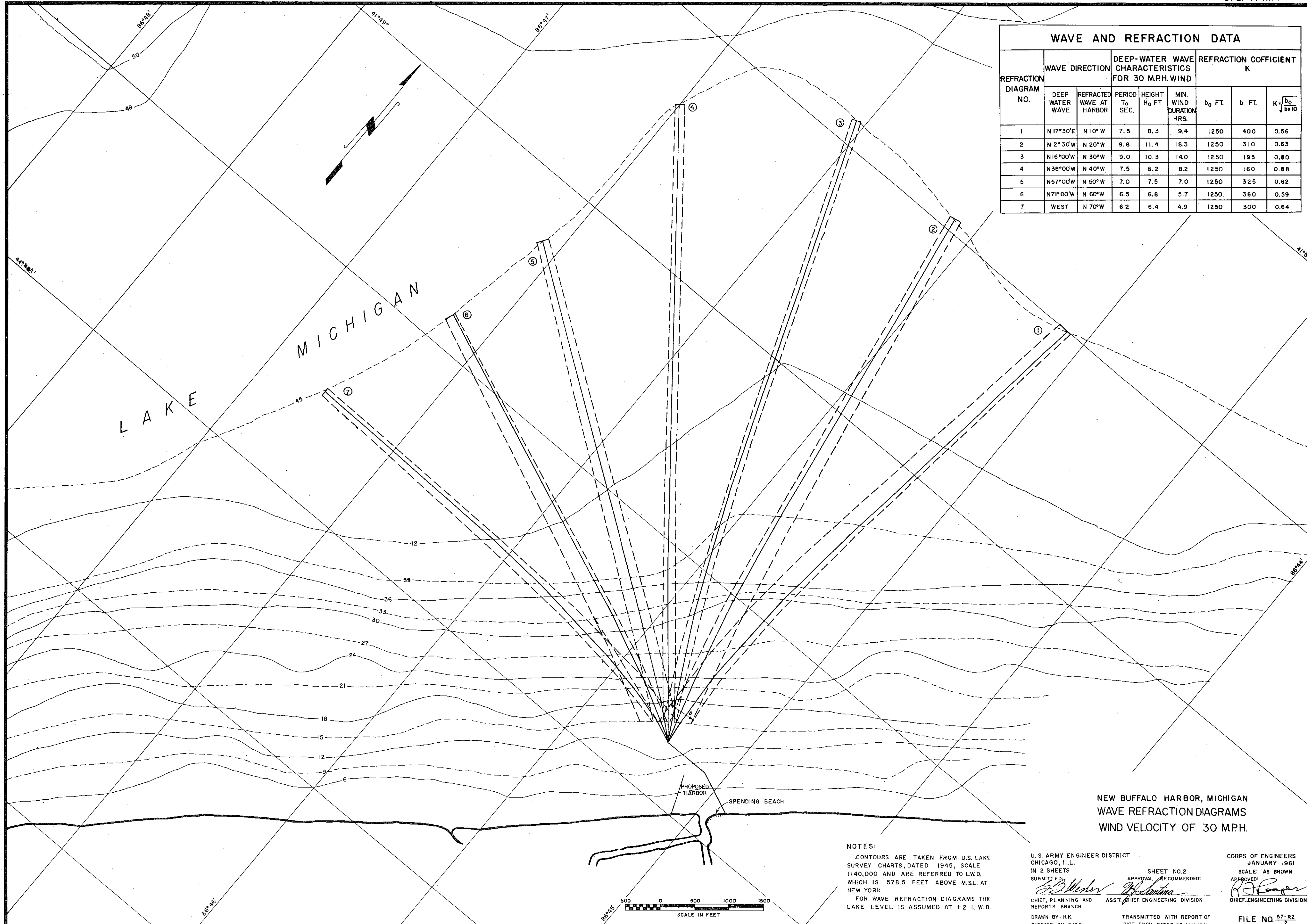

WAVE AND REFRACTION DATA

REFRACTION DIAGRAM NO.	WAVE DIRECTION		DEEP-WATER WAVE CHARACTERISTICS FOR 30 M.P.H. WIND			REFRACTION COFFICIENT K		
	DEEP WATER WAVE	REFRACTED WAVE AT HARBOR	PERIOD T_o SEC.	HEIGHT H_o FT	MIN. WIND DURATION HRS.	b_o FT.	b FT.	$K=\sqrt{\frac{b_o}{b \times 10}}$
1	N 17°30'E	N 10° W	7.5	8.3	9.4	1250	400	0.56
2	N 2°30'W	N 20° W	9.8	11.4	18.3	1250	310	0.63
3	N16°00'W	N 30° W	9.0	10.3	14.0	1250	195	0.80
4	N38°00'W	N 40° W	7.5	8.2	8.2	1250	160	0.88
5	N57°00'W	N 50° W	7.0	7.5	7.0	1250	325	0.62
6	N71°00'W	N 60° W	6.5	6.8	5.7	1250	360	0.59
7	WEST	N 70° W	6.2	6.4	4.9	1250	300	0.64

NEW BUFFALO HARBOR, MICHIGAN
WAVE REFRACTION DIAGRAMS
WIND VELOCITY OF 30 M.P.H.

NOTES:

CONTOURS ARE TAKEN FROM U.S. LAKE SURVEY CHARTS, DATED 1945, SCALE 1:40,000 AND ARE REFERRED TO L.W.D. WHICH IS 578.5 FEET ABOVE M.S.L. AT NEW YORK.

FOR WAVE REFRACTION DIAGRAMS THE LAKE LEVEL IS ASSUMED AT +2 L.W.D.

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CHICAGO, ILL.
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FILE NO. 57-R2/2

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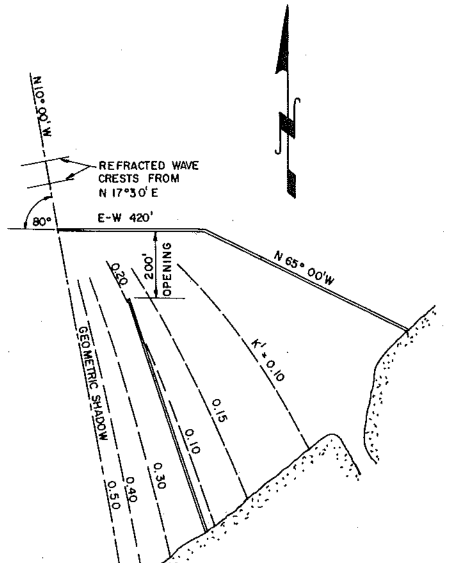


DIAGRAM NO.1
7.5 SEC. PERIOD WAVE FROM N 17°30'E
MAX. WAVE HEIGHT IN HARBOR = 0.7'

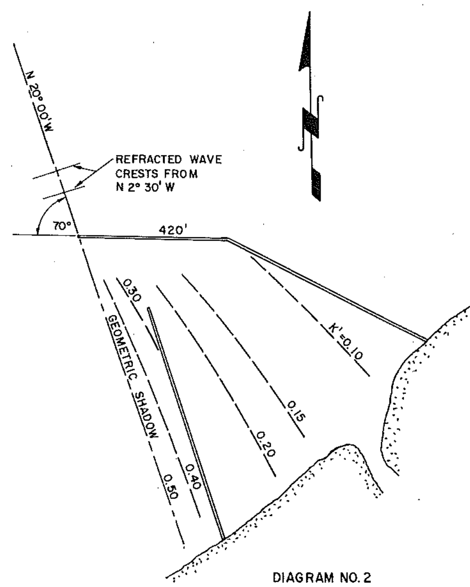


DIAGRAM NO. 2
9.8 SEC. PERIOD WAVE FROM N 2° 30' W
MAX. WAVE HEIGHT IN HARBOR = 1.6'

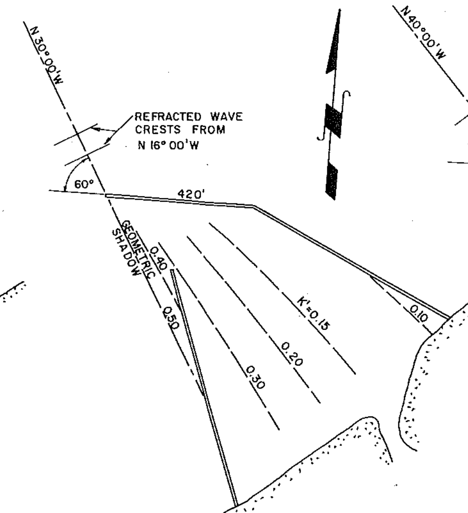


DIAGRAM NO. 3
9.0 SEC. PERIOD WAVE FROM N 16°00'W
MAX. WAVE HEIGHT IN HARBOR = 2.6'

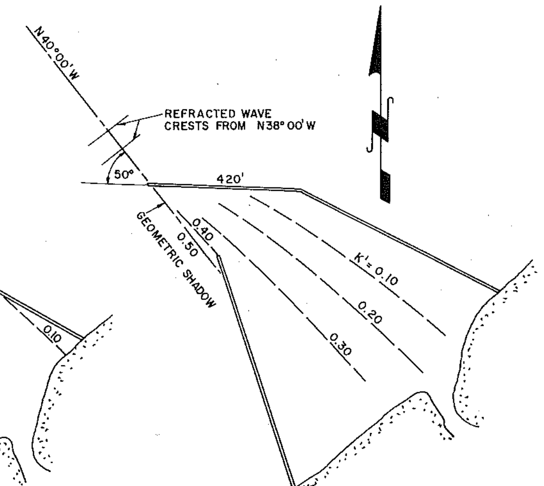


DIAGRAM NO. 4
7.5 SEC. PERIOD WAVE FROM N 38°00'W
MAX. WAVE HEIGHT IN HARBOR = 2.2'

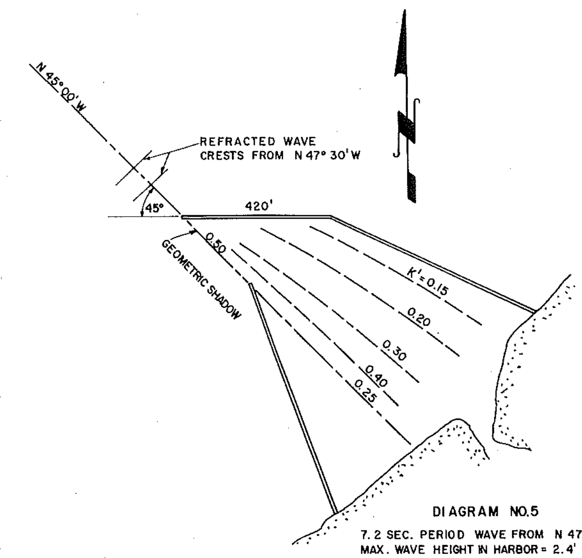
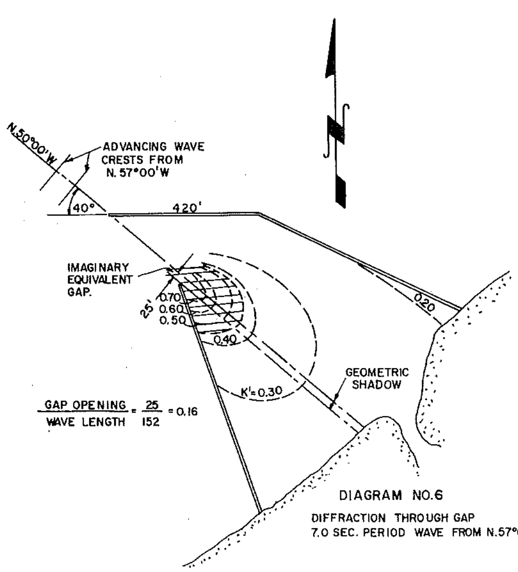
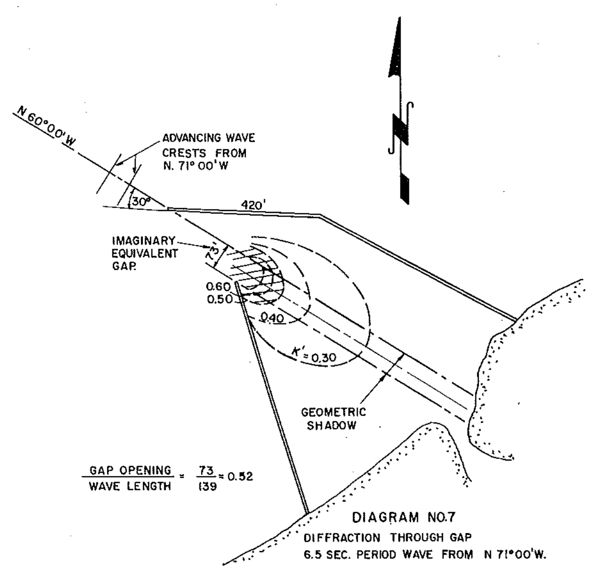


DIAGRAM NO.5
7.2 SEC. PERIOD WAVE FROM N 47° 30' W.
MAX. WAVE HEIGHT IN HARBOR = 2.4'



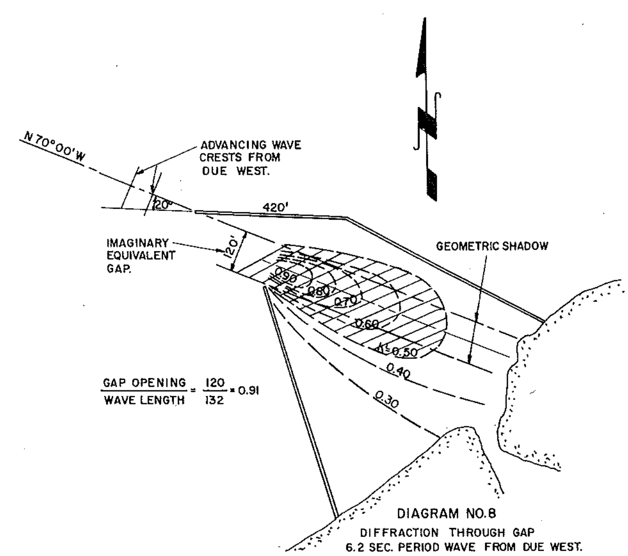
$\frac{\text{GAP OPENING}}{\text{WAVE LENGTH}} = \frac{25}{152} = 0.16$

DIAGRAM NO.6
DIFFRACTION THROUGH GAP
7.0 SEC. PERIOD WAVE FROM N.57°00'W



$\frac{\text{GAP OPENING}}{\text{WAVE LENGTH}} = \frac{73}{139} = 0.52$

DIAGRAM NO.7
DIFFRACTION THROUGH GAP
6.5 SEC. PERIOD WAVE FROM N 71°00'W.



$\frac{\text{GAP OPENING}}{\text{WAVE LENGTH}} = \frac{120}{132} = 0.91$

DIAGRAM NO.8
DIFFRACTION THROUGH GAP
6.2 SEC. PERIOD WAVE FROM DUE WEST.

200 0 200 400 600
SCALE IN FEET

NOTES:

1. DIFFRACTION COEFFICIENT $K' = \frac{\text{DIFFRACTED WAVE HEIGHT}}{\text{INCIDENT WAVE HEIGHT}}$
2. DOTTED LINES DENOTE WAVES OF EQUAL DIFFRACTED WAVE HEIGHTS.
3. ////// DENOTES AREAS IN WHICH WAVE HEIGHT EXCEEDS 2.0' WHERE WAVES ENTER THROUGH GAPS.
4. DIAGRAMS 1-8 SHOW CONDITIONS WITH E-W REACH OF NORTH BREAKWATER (THIS SHEET)
5. DIAGRAMS 1A-8A SHOW CONDITIONS WITH E-W REACH OF NORTH BREAKWATER (SH. NO. 2)
6. FOR WAVE DIFFRACTION DIAGRAMS THE LAKE LEVEL IS ASSUMED AT + 2 L.W.D.

NEW BUFFALO HARBOR, MICHIGAN
WAVE DIFFRACTION DIAGRAMS
WIND VELOCITY OF 30 M. P. H.

U. S. ARMY ENGINEER DISTRICT
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FILE NO. 57-R2/2

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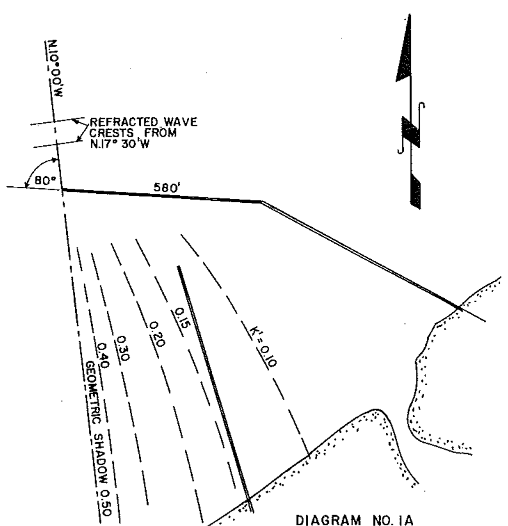

DIAGRAM NO. 1A
7.5 SEC. PERIOD WAVE FROM N.17°30'W
MAX. WAVE HEIGHT IN HARBOR = 0.5'

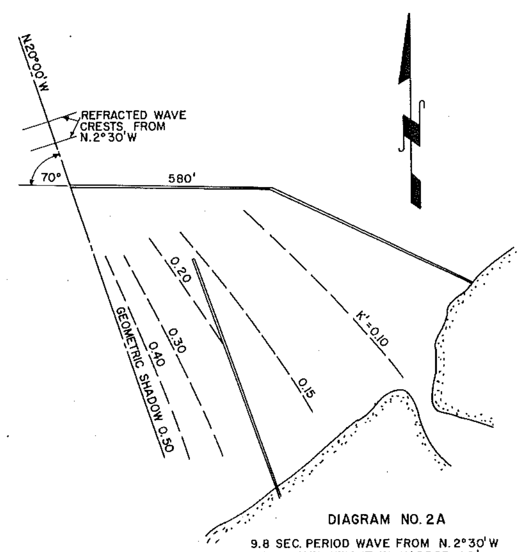

DIAGRAM NO. 2A
9.8 SEC. PERIOD WAVE FROM N.2°30'W
MAX. WAVE HEIGHT IN HARBOR = 1.2'

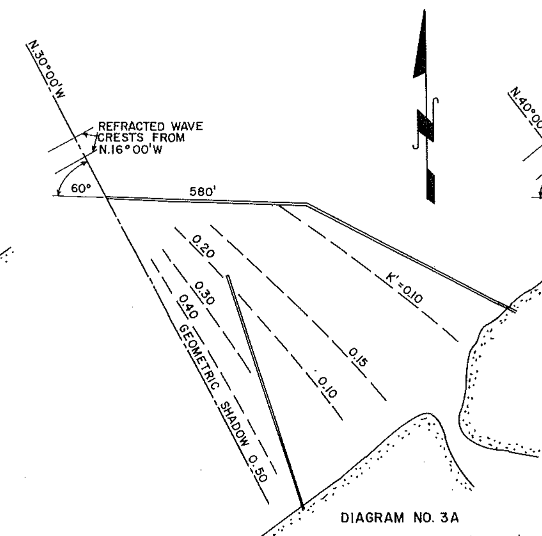

DIAGRAM NO. 3A
9.0 SEC. PERIOD WAVE FROM N.16°00'W
MAX. WAVE HEIGHT IN HARBOR = 1.3'

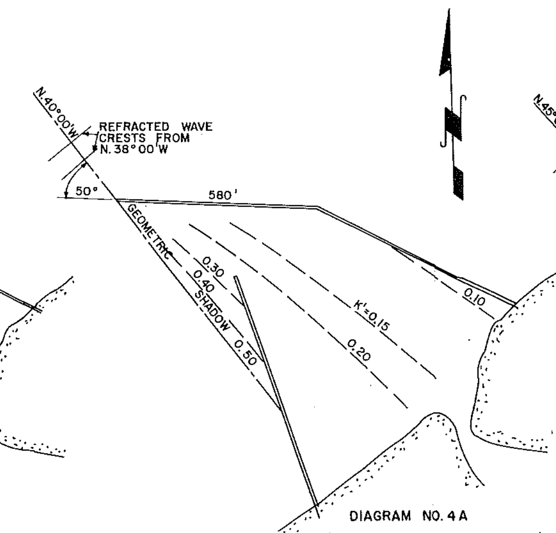

DIAGRAM NO. 4A
7.5 SEC. PERIOD WAVE FROM N.38°00'W
MAX. WAVE HEIGHT IN HARBOR = 1.5'

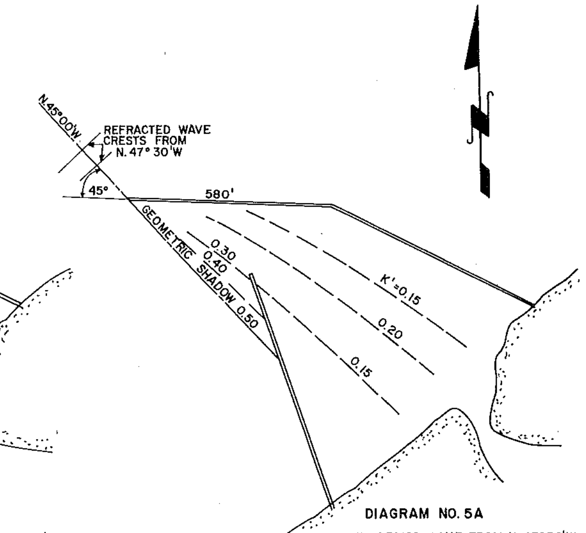

DIAGRAM NO. 5A
7.2 SEC. PERIOD WAVE FROM N.47°30'W
MAX. WAVE HEIGHT IN HARBOR = 1.2'

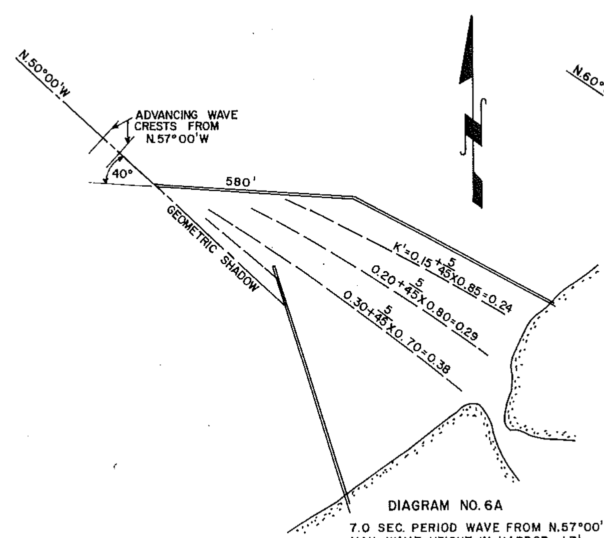

DIAGRAM NO. 6A
7.0 SEC. PERIOD WAVE FROM N.57°00'W
MAX. WAVE HEIGHT IN HARBOR = 1.7'

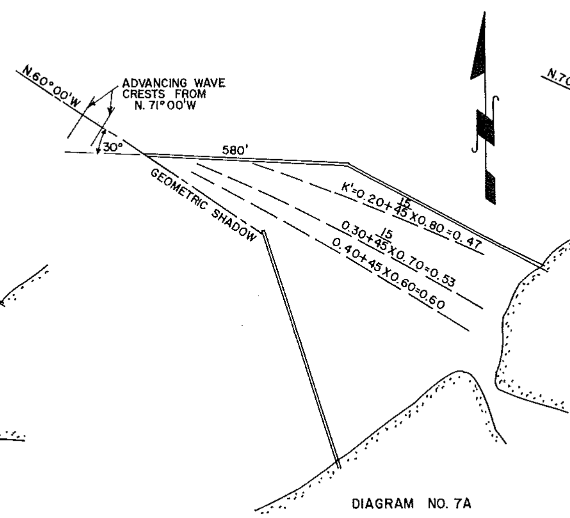

DIAGRAM NO. 7A
6.5 SEC. PERIOD WAVE FROM N.71°00'W
MAX. WAVE HEIGHT IN HARBOR = 2.3'

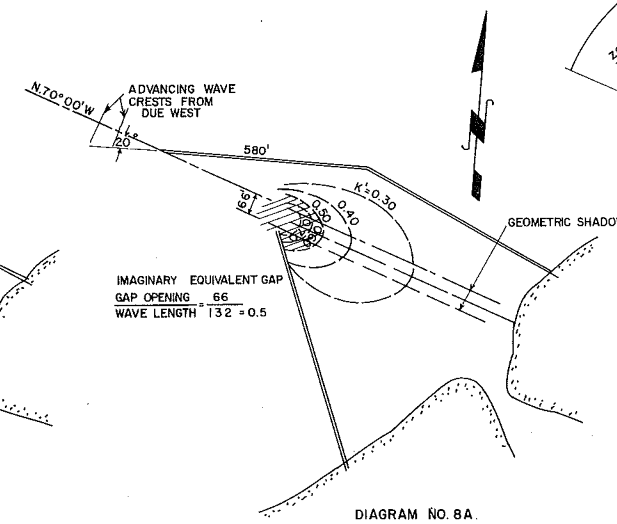

DIAGRAM NO. 8A
DIFFRACTION THROUGH GAP
6.2 SEC. PERIOD WAVE FROM DUE WEST

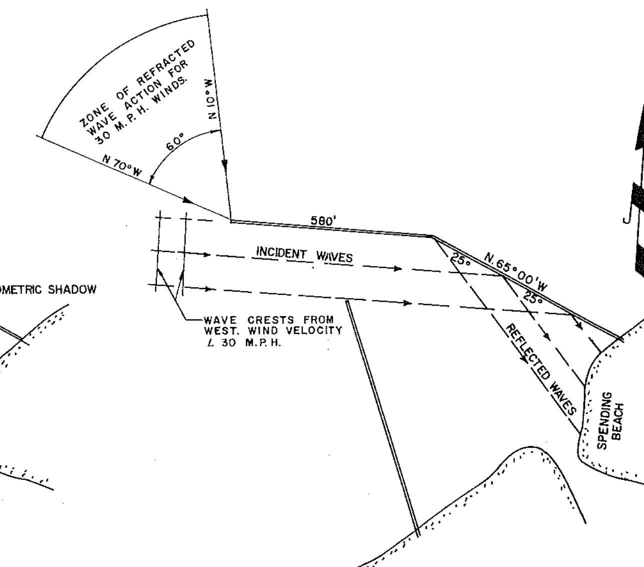

DIAGRAM NO. 9A
SHOWING REFLECTION OF WEST WAVES BY BREAKWATER AND FOCUSING ON SPENDING BEACH

200 0 200 400 600
SCALE IN FEET

NEW BUFFALO HARBOR, MICHIGAN
WAVE DIFFRACTION DIAGRAMS
WIND VELOCITY OF 30 M.P.H.

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CORPS OF ENGINEERS
JANUARY 1961
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FILE NO. 57-R2/2

AUG 1 1961

APPENDIX A, PLATE A-4

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX B - DISCUSSION OF DESIGN AND COST ESTIMATES

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3-5	HARBOR LAYOUT	B-1
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	DESIGN OF BREAKWATER	
7	General	B-2
8	Rubble-mound breakwater	B-2
9	Cellular breakwater	B-3
10	Single-wall cantilever shore connection	B-3
11	CHANNEL DREDGING	B-3
12	COST SUMMARY	B-4

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B-1	Estimate of first cost, rubble-mound breakwater	B-5
B-2	Estimate of first cost, cellular breakwater	B-6

DRAWINGS

Plate number	
B-1	Rubble-mound type breakwater with bulkhead shore connections, file No. 57-R2/2
B-2	Cantilevered steel sheet piling and circular steel sheet pile cell types of breakwater and bulkhead sections, file No. 57-R2/2

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX B - DISCUSSION OF DESIGN AND COST ESTIMATES

GENERAL

1. New Buffalo Harbor is used as a base or port of call for light-draft recreational and commercial fishing vessels. The considered plan of improvement comprises an entrance channel 80 to 180 feet wide by 10 feet deep, 850 feet long, protected by breakwaters of adequate height and width to resist wave forces, together with single-wall shore connections, and an inner channel 80 feet wide by 8 feet deep and 1,250 feet long.

2. The three types of breakwater structures investigated for use at this project were: (a) rubble mound, (b) cellular steel sheet piling with toe protection stone and (c) single-wall steel sheet piling with protection stone at base. The rubble mound type proved to be the most economical and adequate breakwater structure for this harbor and was adopted in the considered plan of improvement. Type (c) is only applicable to water depths of less than four feet and was adopted for shore connections to high ground as shown on the plan, plate B-1.

HARBOR LAYOUT

3. The layout of the New Buffalo Harbor was developed on a basis of providing at a minimum cost a safe and adequate harbor for light-draft vessels, consisting of an entrance channel 10 feet deep, protected by rubble-mound breakwaters on the north and south sides, leading to a deepened inner channel 8 feet deep in the Galien River.

4. The harbor layout has breakwaters which extend the shortest distance from shore to reach adequate permanent lake depth of 12 feet required for small craft, and still have sufficient distance from shore for safety of boats entering and leaving the harbor during storms.

5. Local interests have excavated inland channels from the Galien River; one channel 1,600 feet long by 60 feet wide to Snug Harbor Marina, and another channel 400 feet long by 100 feet wide to New Buffalo Marina.

FOUNDATION MATERIALS

6. Location and logs of foundation jet probings taken in July 1940 are shown on the plan, plate No. B-1. In general, the foundation materials are as follows:

a. At probings 700 feet from shore in vicinity of Reach A of the north breakwater the overlying material is 8 to 10 feet of sand over 2 feet of gravel, all underlain by clay.

b. At probings 300 feet to 600 feet from shore, in vicinity of Reaches B and C of the north and south breakwaters, overlying material is 10 feet of sand with a 2-foot gravel interlayer, all underlain by clay.

c. Near shore, in Reaches D and E, the foundation materials are similar to those in Reach C. With the 20-foot maximum height of breakwater, 7 feet being above L.W.D., the strength of foundation is considered adequate to support either the rubble-mound type of breakwater or cell fill with limited settlement.

DESIGN OF BREAKWATER

7. GENERAL

The breakwater is a structure employed to reflect and dissipate the force of the wind-generated waves, thereby providing shelter and protection for ships in the harbor.

The factors affecting breakwater design are:

a. Geographic location on southeast shore of Lake Michigan.

b. The climatic conditions and temperature.

c. Lake conditions and storm wave action.

d. Availability of large amounts of durable rock and of concrete materials.

e. The cost of breakwater construction and maintenance.

8. RUBBLE-MOUND BREAKWATER

Reach A of the north rubble-mound breakwater has an average depth of water of 12 feet. The depth of water varies from 8 feet in Reach B, to from 4 to 7 feet in Reach C for north and south breakwaters. The breakwater section consisting of a core of quarry run rock, placed on a layer of bedding stone, and covered by a layer of heavy cap stones of 8- to 12-ton, has a top width of 12 feet, 7 feet above L.W.D. and 1 on 1.5 side slopes.

The design of the rubble-mound type of breakwater was based on:

a. Iribarren formula, as modified by Hudson for determination of weight of cover stone.

"A formula for the Calculation of Rockfill Dikes" by C. R. Iribarren.

U. S. Beach Erosion Board - Bulletins V-3, N 1, January 1949.
U. S. Beach Erosion Board - Bulletins V-5, N 1, January 1951.

b. "Wave Forces on Breakwaters" by R. Y. Hudson A.S.C.E. Transactions Vol. 118, 1953, pages 653 to 685.

9. CELLULAR BREAKWATER

As an alternative structure, a cell-type breakwater was considered. Reach A of the north breakwater has an average depth of water of 12 feet. The depth of water varies from 8 feet in Reach B, to from 4 feet to 7 feet in Reach C of the north and south breakwaters. The diameters vary from 33 to 22 feet. Design of cellular-type breakwater is based on Paper No. 1316, Proceedings ASCE, September 1957 by E. M. Cummings titled: "Cellular Cofferdams and Docks." The foundation material was assumed to be loose sand, saturated weight 125 lbs. per cu. ft., submerged weight 62.5 lbs. per cu. ft. $\phi = 25°$. Fill material was assumed to be rock, having a saturated weight of 125 lbs. per cu. ft. and $\phi = 35°$. The minimum factor of safety against tilting is 1.5. The top elevation of the structure will be 585.5 (7' above L.W.D.).

10. SINGLE-WALL CANTILEVER SHORE CONNECTION

The single-wall sheet pile breakwater for north and south shore connections was designed as a cantilever. The efficiency factor for passive pressure was assumed equal to unity. The allowable stresses in bending were assumed at 20,000 p.s.i. The top elevation of the wall to be 585.5 (7' above L.W.D.). The wave forces used in the design of all types of breakwaters are given in appendix A.

CHANNEL DREDGING

11. The entrance channel is to be dredged to a project depth of 10 feet plus 1-foot overdepth for widths of 80 to 180 feet with 1 on 2 side slopes and a length of 850 feet, whereas the inner channel is to be dredged to 8-foot depth plus 1-foot overdepth for 80-foot width, 1 on 2 side slopes, and 1,250-foot length. Alternative methods of dredging and spoil disposal were investigated. It was found that hydraulic pipeline dredging with spoil disposal on nearby land would cost $0.75 per cubic yard,

and dipper dredging with spoil disposal in Lake Michigan would cost $1.40 per cubic yard. As spoil from the initial dredging will be used on the beach nourishment stockpile nearby, the former method was selected for the considered plan of improvement.

12. COST SUMMARY

A summary of the estimates of cost for the considered improvements of New Buffalo Harbor is given in the main report. This appendix presents more detailed information. Table B-1 and table B-2 show cost of alternate types of breakwater construction. The costs are based upon August 1961 price levels which were determined by examination of bids received recently for work of a similar nature. The stone for this construction can be obtained most economically from native quarries such as those at Bedford, Indiana. The costs shown herein are based on stone, from Bedford. Stone quantities shown do not include provision for the possibility of limited settlement noted in paragraph 6. Estimated annual maintenance costs provide for repairing such future settlement.

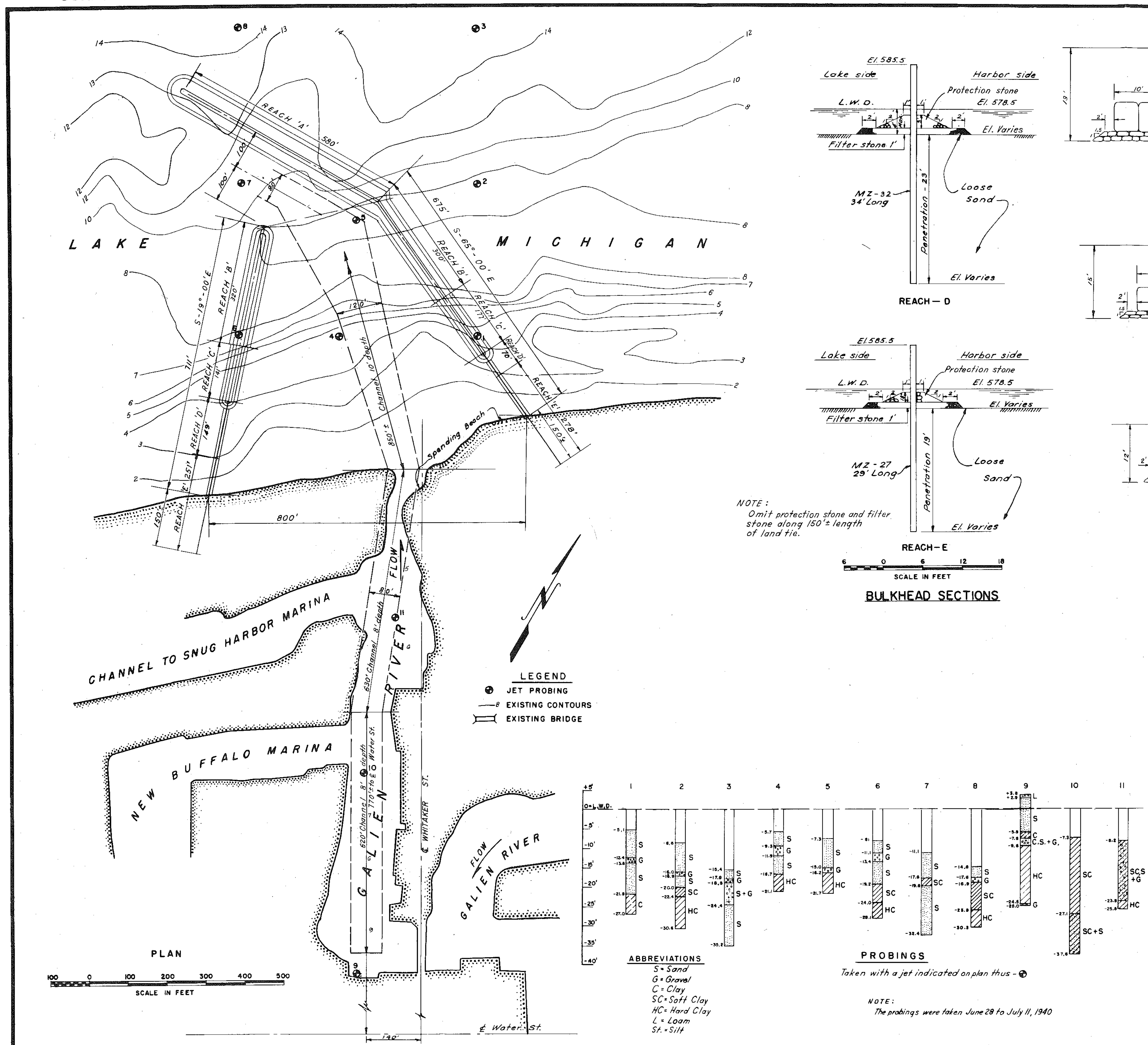
Table B-1 - Estimate of first cost, rubble-mound breakwater

Item		Amount
Federal first cost		
Excavation:		
Entrance and inner channel,	49,000 c.y. @ $0.75	$ 37,000
Beach nourishment stockpile,	251,000 c.y. @ 0.65	163,000
Contingencies		30,000
Subtotal, channel excavation		230,000
Breakwater construction:		
Cap stone	31,000 tons @ $14.00	434,000
Core stone - quarry run	12,300 tons @ 11.00	135,300
Bedding stone	8,350 tons @ 10.00	83,500
Steel sheet piling	7,500 s.f. @ 4.50	33,800
Steel sheet piling	14,900 s.f. @ 3.80	56,600
Filter stone	340 tons @ 6.00	2,000
Protection stone	260 tons @ 11.00	2,900
Contingencies		149,900
Subtotal, breakwater construction		898,000
Total, construction cost		1,128,000
Engineering, design, and model study		70,000
Supervision and administration		84,000
Total, general navigation facilities		1,282,000
Preauthorization study cost		15,000
Total, Corps of Engineers		1,297,000
Aids to navigation, lump-sum, Coast Guard		5,000
Total Federal first cost		1,302,000
Non-Federal first cost, public		
Rights-of-way 3 acres		21,000
Total project first cost		1,323,000

Table B-2 - Estimate of first cost, cellular breakwater

Item		Amount
Federal first cost		
Excavation:		
Entrance and inner channel,	49,000 c.y. @ $0.75	$ 37,000
Beach nourishment stockpile,	251,000 c.y. @ 0.65	163,000
Contingencies		30,000
Subtotal, channel excavation		230,000
Breakwater construction:		
Cap stone	7,445 tons @ $14.00	104,200
Bedding stone	5,700 tons @ 6.00	34,200
Stone fill for cells	17,650 tons @ 6.00	105,900
Filter stone	4,100 tons @ 6.00	24,600
Protection stone	5,548 tons @ 11.00	61,000
Steel sheet piling	154,700 s.f. @ 3.95	611,100
Steel sheet piling	14,900 s.f. @ 3.80	56,600
Steel sheet piling	7,500 s.f. @ 4.50	33,800
Contingencies		206,600
Subtotal, breakwater construction		1,238,000
Total, construction cost		1,468,000
Engineering, design, and model study		74,000
Supervision and administration		100,000
Total, general navigation facilities		1,642,000
Preauthorization study cost		15,000
Total, Corps of Engineers		1,657,000
Aids to navigation, lump-sum, Coast Guard		5,000
Total, Federal first cost		1,662,000
Non-Federal first cost, public		
Rights-of-way, 3 acres		21,000
Total project first cost		1,683,000

CORPS OF ENGINEERS U.S. ARMY



NEW BUFFALO HARBOR, MICHIGAN

RUBBLE MOUND TYPE BREAKWATER WITH BULKHEAD SHORE CONNECTIONS SECTIONS

U.S. ARMY ENGINEER DISTRICT CHICAGO, ILL.

CORPS OF ENGINEERS JANUARY 1961 SCALE: AS SHOWN

SUBMITTED: CHIEF, DESIGN BRANCH

APPROVAL RECOMMENDED: ASS'T CHIEF, ENGINEERING DIVISION

APPROVED: CHIEF ENGINEERING DIVISION

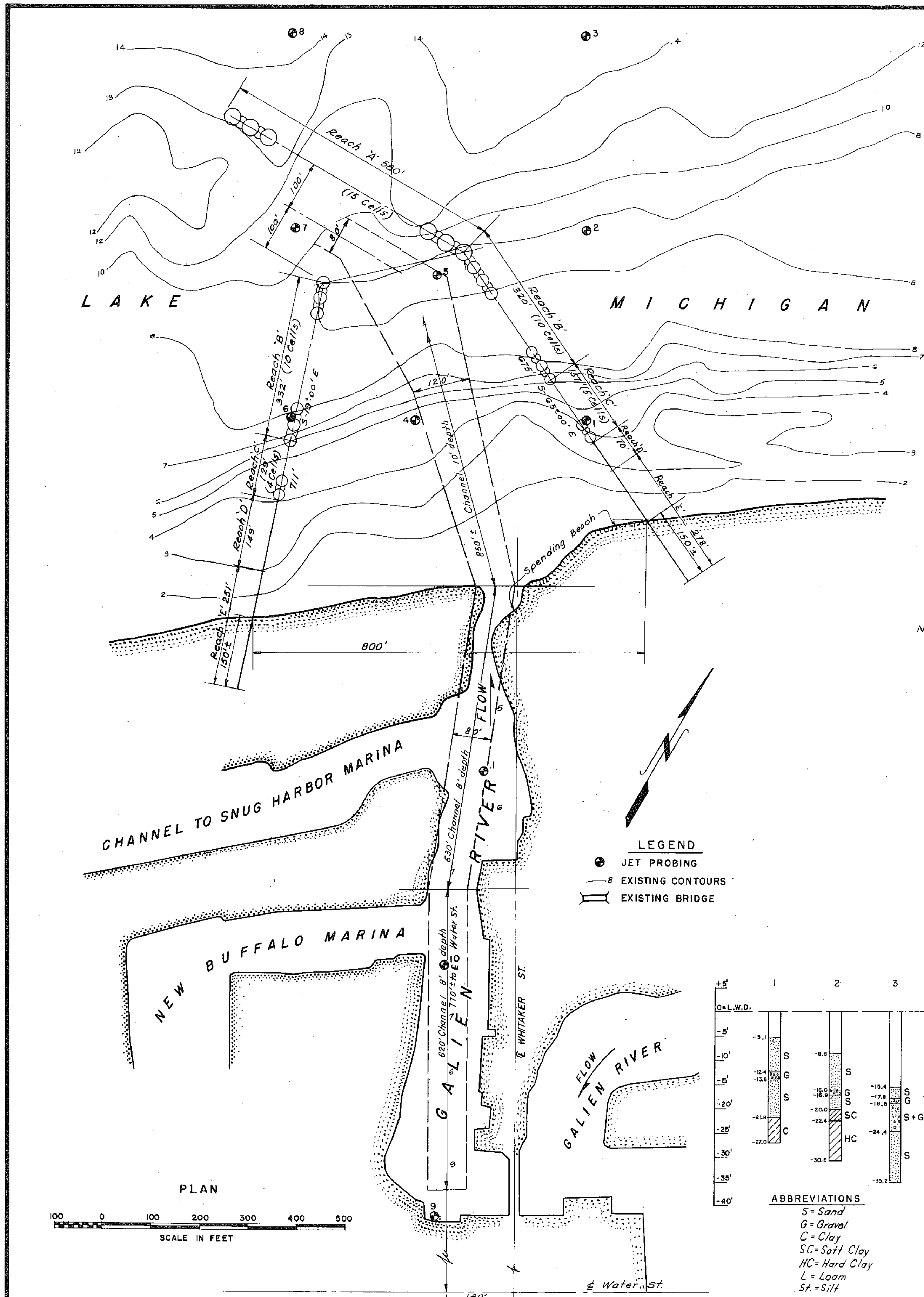
DRAWN BY: AL.K. CHECKED BY: W.F.B.

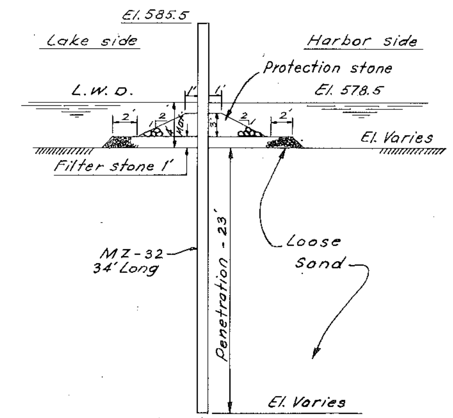
TRANSMITTED WITH REPORT OF DIST. ENGR. DATED

FILE NO. 57-R2 2

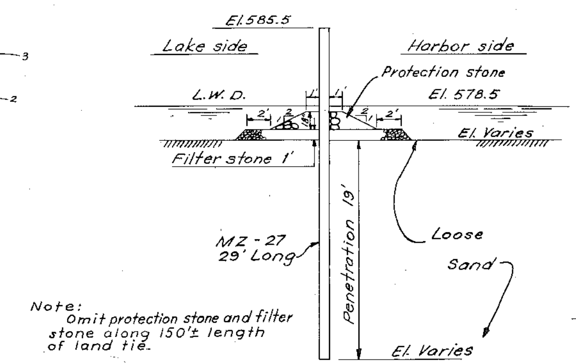
AUG 1 1961

PLATE B-1





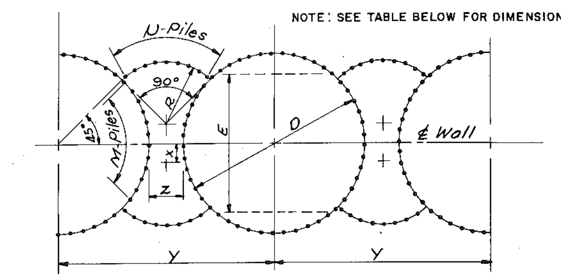
REACH — D



REACH — E

SCALE IN FEET

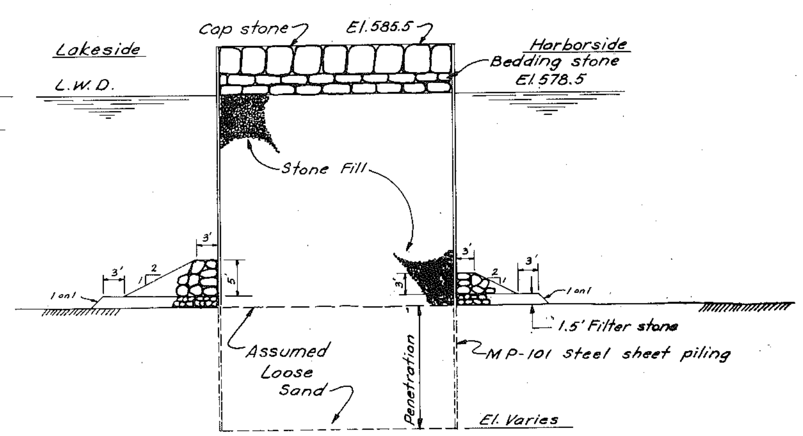
BULKHEAD SECTIONS



TYPICAL PLAN - S.S. PILE CELLS

NOT TO SCALE

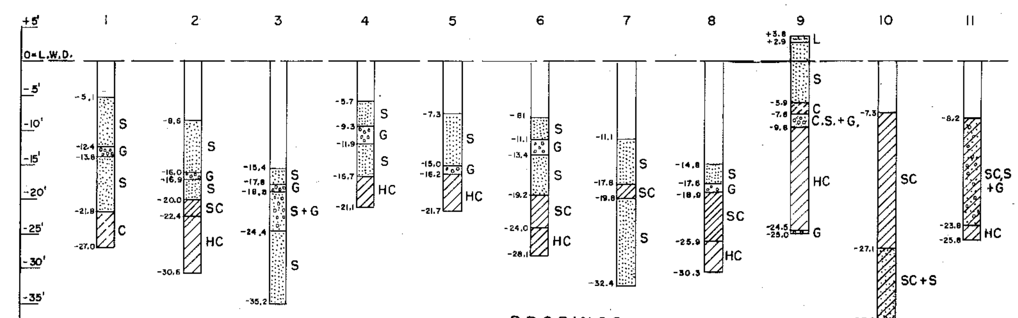
Reach	Length of Pile Feet	Penetration in Feet	Number of Piles in Cell	D Feet	Y Feet	Number M-Piles	R Feet	Number N-Piles	X Feet	Z Feet	E Feet	Area - Sq. Ft. Within Circle	Area - Sq. Ft. Between Circle
A	38	18	84	33.42	38.32	20	10.39	12	4.46	4.9	27.90	876.2	249.7
B	27	12	64	25.46	31.61	15	9.6	11	2.23	6.15	21.52	510.7	204.5
C	23	10	56	22.28	28.22	13	8.8	10	1.66	5.94	18.94	390.6	169.6



REACH — A, B & C

SCALE IN FEET

CELL SECTION



ABBREVIATIONS
S = Sand
G = Gravel
C = Clay
SC = Soft Clay
HC = Hard Clay
L = Loam
St. = Silt

PROBINGS

Taken with a jet indicated on plan thus -

NOTE:
The probings were taken June 28 to July 11, 1940

NEW BUFFALO HARBOR, MICHIGAN
CANTILEVERED STEEL SHEET PILING
& CIRCULAR STEEL SHEET PILE CELL TYPES
OF BREAKWATER & BULKHEAD SECTIONS

U.S. ARMY ENGINEER DISTRICT
CHICAGO, ILL.

CORPS OF ENGINEERS
JANUARY 1961
SCALE: AS SHOWN

SUBMITTED: E. Hoffmann
CHIEF, DESIGN BRANCH

APPROVAL RECOMMENDED: [signature]
ASS'T. CHIEF, ENGINEERING DIVISION

APPROVED: R. J. [signature]
CHIEF, ENGINEERING DIVISION

DRAWN BY: A.L.K.
CHECKED BY: W.F.B.

TRANSMITTED WITH REPORT OF
DIST. ENGR. DATED [illegible]

FILE NO. 57-R2 / 2

AUG 1 1961

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX C - EFFECT OF PROPOSED HARBOR ON SHORELINE

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U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX C - EFFECT OF PROPOSED HARBOR ON SHORELINE

1. INTRODUCTION

In this appendix the effect of the proposed harbor at New Buffalo, Michigan on adjacent shorelines is considered in detail. The predominant direction of littoral drift, amount of littoral drift and annual harbor maintenance are estimated and a plan for reducing erosive processes is presented. Among other factors, the direction of littoral drift influences the location of the harbor entrance. An optimum entrance location based on littoral drift direction is selected.

2. PREVIOUS REPORTS

A cooperative beach erosion control study for Berrien County, Michigan was printed in 1958 as H.D. No. 336, 85th Congress, 2d Session. This report considered the shoreline from the Michigan-Indiana state line to the north city limit of Benton Harbor, a reach of 32 miles, which includes the study area. No beach erosion control study for the Indiana shoreline has been made. Information and findings in the Berrien County report are used in this appendix.

3. LITTORAL PROCESSES

As waves generally break at an angle to the shoreline, an along-shore, or "littoral current" is generated by the component of wave forces parallel to the shoreline. This current, along with the agitating action in the breaker zone, is the primary cause of sedimental movement along a shoreline.

4. Geologically, a particular reach of shoreline may be accreting, eroding or stable. The status of the reach depends on the relative rates of supply and loss of littoral materials. Changes in geological status are slow and over long periods of time natural shoreline areas, if unaltered by man-made structures, are generally stable. The along-shore component of wave energy is the major force causing the littoral transport. Thus, for stability, the average annual rates of supply and loss of materials are equal for the average annual wave energy expended.

The addition of man-made structures acts as local barriers to the littoral drift causing imbalance in these rates and gradual shoreline changes until the material supply is again balanced. Insufficient littoral supply causes depletion and over-supply causes accretion along shorelines.

5. To reach well-founded conclusions on the probable effect of structures on shorelines, the following physical factors must be considered:

a. Source and characteristics of littoral material.

b. Direction of littoral transport.

c. Rates of supply and loss of materials.

Available data and comparisons with conditions at other harbors provided the means for evaluating these factors at New Buffalo.

6. SOURCES OF LITTORAL MATERIALS

The sources of littoral material are tributary streams discharging silt loads, bluff erosion and slides and onshore movement of sand by wave energy and wind action. The significant shore region in which the littoral processes may affect shorelines at the site extends from St. Joseph Harbor to Michigan City Harbor. This shore region is so limited because shoreline phenomena within the region are not affected by the physical conditions in adjacent regions.

7. The largest streams that discharge bed material loads along the significant shore segment are the St. Joseph River and the Galien River.

8. The St. Joseph River, with a drainage area exceeding 4,500 square miles, enters St. Joseph Harbor before discharging into the lake. Since the mouth is dredged it acts as a settling basin for all but the finest sediments. The sedimentary load is removed from the harbor by dredging. From 1906 to 1915 the harbor dredging averaged about 41,500 cubic yards per year for a 16-foot project depth. Over the 15-year period, 1940-1954, dredging averaged about 90,000 cubic yards per year for a 21-foot project depth. Therefore this river now contributes little to the littoral drift.

9. The Galien River, with a drainage area of about 180 square miles, discharges into New Buffalo Harbor before reaching the lake. The lower reach of the river has little velocity and meanders through a valley. It is probable that much of the bedload is deposited in these lower reaches and little beach-building material is contributed to shorelines by the river. The construction of the proposed harbor will provide a settling basin in which some sediments would be deposited.

10. An estimate of dredging due to river sediments was made from records at St. Joseph Harbor which indicate annual dredging of about 20 cubic yards per square mile of drainage area. On this basis the annual harbor dredging due to Galien River sediments would not exceed 4,000 cubic yards per year and it would contribute little to the littoral drift.

11. A main source of littoral drift in the shore segment considered is from bluff erosion and slides. The shores for about a mile north of St. Joseph Harbor and 1,200 feet south thereof have been advancing lakewards since the entrance jetties were built. South of the latter accreting area, however, erosion of the bluffs has been severe, causing valuable residences to be lost or moved and other damage. In recent years (1943 to 1954), due to the cycle of high lake levels, the recession of the bluffs has been intensified. The rate of bluff recession from St. Joseph Harbor south to Shoreham, a distance of about 3 miles, has averaged 2.1 feet annually. This is the area for which a plan for beach erosion control consisting of artificial beaches and nourishment has been recommended by the Chief of Engineers in H.D. No. 336, 85th Congress, 2d Session. Erosion has also occurred southwesterly of New Buffalo. For shore protection, private interests have built 27 seawalls and revetments in a 2-mile reach from Michiana Shores to Grand Beach. (See plate A-1, appendix A for location.)

12. Whenever sandy beaches exist dunes are in process of formation. Prominent dune formations extend from St. Joseph Harbor southwestwards to New Buffalo. They consist of a broken belt of high dunes, a quarter of a mile to a mile or more in width bordering the lake. Some dunes are 200 feet above lake level. The dunes were built of sand eroded from morainic bluffs and carried by littoral currents to the shore and deposited on the beach by waves. The sand dries out and is borne landward by inshore winds. These dunes are easily erodible and when reached by waves contribute materially to the littoral drift.

13. Another source of littoral drift is from the offshore areas. Volumetric studies show that erosion of the offshore bottom to the 20-foot contour in the reach of shore involved has accompanied bluff recession.

14. CHARACTERISTICS OF MATERIAL

Extensive analyses of beach, bluff and offshore materials are available in H.D. No. 336 referred to in paragraph 2 above. Generally the finest material found on beaches is about 0.149 millimeter (100 mesh). About 98% of beach material is retained on the 100 mesh sieve. The offshore material generally passes the 100 mesh sieve and is retained on the 200 mesh size of 0.074 millimeter. Analysis of bluff material south of St. Joseph shows that about 32% of the material is coarser than 100 mesh, and therefore could be a source of beach materials.

15. DIRECTION OF LITTORAL DRIFT

The predominant direction of littoral drift is a necessary part of the factual data for shoreline studies. The best indications of drift are found in the shoreline patterns of existing shoreline structures. Accretion at a structure occurs updrift of the littoral current and depletion occurs downdrift due to reduction in littoral material. Another indication of drift direction is found by means of a vector diagram of wave energy components at the site. Both methods are used in this appendix.

16. The predominant direction of littoral drift along the east shore of the lake is from north to south as indicated by greater accumulations of material to the north of the harbor structure at St. Joseph, and to the north of smaller individual structures, located north and south of the harbor. Short time reversals are indicated by sand deposits south of the St. Joseph Harbor entrance.

17. The proposed New Buffalo Harbor is located between the existing harbors at St. Joseph and Michigan City, both of which have established characteristic shoreline patterns of accretion along the shores northeast of the harbors and erosion along the shores southwest of the harbors. Since the direction of littoral drift is from northeast to southwest at both harbors it seems clear that this is the predominant direction at the site.

18. A prominent groin, 200 feet long about 3.5 miles southwesterly from New Buffalo shows in aerial photographs a sand accretion along the shoreline northeast from the structure. These photographs also show nearly equal sand accretion on both sides of the existing parallel piers at New Buffalo. The lengths and present condition of these piers do not permit sand accretions which would indicate the drift direction at this point. A comparison of local surveys for 1925 and 1940 shows that a lakeward progression of the northeast shoreline of about 250 feet on the average in a quarter mile from the north pier occurred with little change in the same length of southwest shoreline during the 15-year period.

19. Since wave energy is the primary factor causing littoral transport, an indication of the direction of littoral drift is found by a vector diagram of wave energy components. A diagram for the site was prepared from data for Chicago and Muskegon Harbors in Technical Memorandum No. 36 of the Beach Erosion Board, "Wave and Lake Level Statistics for Lake Michigan."

20. The significant wave directions affecting littoral drift at New Buffalo range from W through N to NNE. It was assumed that winds from N and NNE at Chicago, and those from W, WNW, NW and NNW at Muskegon, also prevailed at New Buffalo with the same durations and wind speeds for the purpose of calculating energy at New Buffalo. For the full year this shows that waves exceeding 0.5 foot prevailed at New Buffalo 37.6% of the time as compared to 30.5% at Chicago and 56.7% at Muskegon.

Using the full-year energy values, durations for each direction and fetch, the mean value of HT^2 was found from the approximate energy equation $E = 7.195 \times 10^4 HT^2D$, where H = deep-wave height in feet, T = period in seconds, D = annual duration of waves in hours and E = annual energy in foot pounds per foot of wave crest. A pair of mean values of H and T to satisfy the equation were found from the wave-forecasting chart by trial. The corresponding values of H and T were then read from the chart for the fetch at New Buffalo and the same wind speed, from which the New Buffalo energies were evaluated. These energies are for deep-water waves. The refracted wave directions were used and found from refraction data in appendix A. Table C-1 shows data used to prepare the vector diagram shown in figure 1.

Table C-1 - Annual wave energy at New Buffalo

Deep water wave direction	Refracted wave direction	Energy at: Chicago (1)	Energy at: Muskegon (1)	Annual duration of waves in hours: Chicago	Annual duration of waves in hours: Muskegon	Energy at New Buffalo (1)	Percent of time of wave occurrence
NNE	N7°30'W	9.2	-	484	-	8.3	5.5
N	N18°30'W	13.1	-	596	-	19.6	6.8
NNW	N35°00'W	-	8.8	-	538	9.6	6.1
NW	N45°00'W	-	9.3	-	482	7.3	5.5
WNW	N55°00'W	-	8.6	-	418	6.8	4.8
W	N70°00'W	-	20.9	-	782	11.9	8.9
							37.6
			Calm or wave height less than 0.5'				62.4

(1) Energies in table equal foot-pounds per foot of wave crest per year $\times 10^{-8}$

21. The shoreline and nearshore lake contour direction of N50°E used was taken from lake survey charts. The diagram shows alongshore average annual energy components of 12.5×10^8 ft. lbs. per foot of wave crest directed S50°W and 8.4×10^8 ft. lbs. per foot of wave crest directed N50°E or a net annual component of 4.1×10^8 ft. lbs. per foot of wave crest directed S50°W. This indicates that there are reversals in drift movement, but that the predominant movement is to the SW. This supports the evidence of SW drift direction indicated at existing structures.

22. RATE OF LITTORAL DRIFT

The annual rate of littoral drift at New Buffalo is based on studies made for the cooperative beach erosion control survey report for Berrien County, Michigan, and published as H. D. 336, 85th Congress, 2d Session.

These studies have determined that the rate of littoral drift in the reach generally from St. Joseph Harbor to Michigan City Harbor is on the order of 100,000 cubic yards per year. This is discussed in the following paragraphs.

23. At St. Joseph Harbor it is known that for the period 1907-1954, the accretion north of the harbor jetties averaged 75,000 cubic yards per year. For the period 1950-1956, an average accretion of 28,600 cubic yards occurred in the 3.5-acre area immediately lakeward of the entrance to the channel in a 22-foot depth. The best estimate for material reaching the harbor area from the north is that given by the average accumulation in the 1907-1954 period plus the amount which passes around the north jetty or about 100,000 cubic yards per year. It is probable that no drift bypasses the harbor entrance to the downdrift shore as maintenance dredging is performed annually.

24. It has been assumed that the capacity and application of littoral forces for transporting material alongshore in the littoral zone are similar immediately north and south of St. Joseph Harbor. This is borne out by volumetric computations for the area from St. Joseph to Shoreham. Erosion of bluff material in this reach averaged 100,000 cubic yards per year (1872-1954). Erosion from the offshore bottom to the 20-foot contour in the same region averaged 160,000 cubic yards per year (1872-1954). About one-third of the bluff material, and probably not more than one-half of the offshore material, is available as littoral drift. It appears that the net rate of littoral drift in the region from St. Joseph Harbor to Shoreham was also of the order of 100,000 cubic yards annually.

25. On the above basis the potential rate of littoral transport in the vicinity of the proposed New Buffalo Harbor might be approximated at 100,000 cubic yards per year. This rate appears reasonable for determination of rate of filling of the impounding area and for determination of annual maintenance dredging.

26. IMPOUNDING AREA

Since accretion has occurred on the updrift sides and erosion on the downdrift sides of the harbor structures at St. Joseph and Michigan City, a similar pattern is expected to develop at the proposed harbor site. The alignment of the accreted shoreline would tend to become normal to the annual resultant of wave energy. (See figure 1.) An accretion area of about 4,700 square feet at L.W.D. and about one mile in length would result alongside the north breakwater with a shoreline advance of about 600 feet at the breakwater. At Michigan City Harbor accretion extends over more than a mile of shoreline east from the east pier. At St. Joseph Harbor accretion extends about one mile north from the north jetty. The anticipated accretion north of New Buffalo Harbor would comprise an impounding volume estimated at 460,000 cubic yards.

Since the proposed harbor is in relatively shallow water, the fairly high rate of littoral drift is expected to fill in the impounding area above the north breakwater in about 5 years. The major part of the littoral drift would thereafter again bypass New Buffalo and be available for the downdrift shore.

27. ANNUAL DREDGING

It has been estimated in paragraph 10 that the average sediment from Galien River which would be deposited in New Buffalo Harbor would be about 4,000 cubic yards annually. In addition, a portion of the littoral drift moving along the north breakwater will form a shoal in the wave lee of this structure in the zone of decreased wave energy. The portion of the littoral drift which will be deposited in the outer harbor channel can only be estimated by analogy and other indirect methods. However, based on experience at Michigan City Harbor, and recognizing that the littoral drift deposition in the channel would increase after the initial impoundment north of the harbor, it is estimated that the average annual dredging of the outer harbor channel at New Buffalo over the life of the project would be 10,000 cubic yards. Total average annual dredging, including Galien River sediment, is 14,000 cubic yards.

28. EXISTING EROSION

The Galien River enters the lake about five miles north of the Michigan-Indiana State line. In this reach a belt of sand dunes one-half mile in width borders the lake front. All frontage is privately owned. Many cottages and homes of year-round residents front directly on the lake. In one-half mile southwesterly from the river there are 18 residences located about 200 feet from the lake. In the three-mile reach southwest from the river to Grand Beach there are no protective structures. In the two-mile reach from Grand Beach to Michigan Shores, at the State line, erosion is in progress. Owners have built 20 revetments and sea-walls and 7 groins for protection against erosion in that reach. At Michigan Shores, a portion of the lakeshore road has been lost due to erosion. There is no evidence of a cooperative effort to combat erosion with the result that, in some cases, properties adjoining those protected have been eroded to such an extent that protective works have been outflanked. A coordinated plan to protect this area requires protective beaches (Ref.: H.D. No. 336, 85th Congress, 2d session). The Galien River does not have a high, average discharge. Dredging at the mouth is infrequent. The existing timber entrance piers at the mouth of the Galien River, constructed by local interests around the turn of the century, have deteriorated, are no longer effective for trapping sand. Therefore, littoral drift must be bypassing the mouth probably over sand bars. For these reasons, the present effect of the existing harbor on downdrift shore erosion is considered negligible.

29. PROBABLE SHORELINE CHANGES

The construction of the harbor will create a short, downdrift shore segment extending about 10 miles to the harbor at Michigan City. Along this shore erosion, additional to the present amount, can then be expected and would be no less than the amount of material impounded by the structures. The initial shore is expected to extend about three miles from the harbor to Grand Beach. No protective structures exist in that reach. Using the rule of thumb equation wherein one square foot of surface area equals one cubic yard of beach material the average, annual loss of shoreline during filling of the impounding area would be a strip about 6.5 feet wide and 3 miles long. The reach of shoreline extending about one-fourth mile south of the St. Joseph harbor entrance has been accreting due to reversals in the direction of littoral drift, while south of that reach erosion is in progress. These conditions are assumed for the proposed harbor since drift reversals are also occurring.

30. REMEDIAL MEASURES

a. General

The considered remedial measures are those necessary to restrict the erosion expected to be caused by the proposed harbor. These consist of artificial nourishment from a stockpile while the impounding area fills to capacity, after which the material from harbor maintenance dredging is used for periodic nourishment. The stockpile material is then distributed naturally along the shoreline by the waves and currents, accompanied by a progressive sorting of materials on the beach. To date no satisfactory method of sand by-passing has been found which offers any improvement over the proven methods of periodic nourishment of beach material by hydraulic pipeline dredge. The remedial measures involve the selection of a suitable beach material, artificial nourishment plan, location and dimensions of the stockpile, and method of placing fill on beach.

b. Beach material

The ideal sand selected for artificial nourishment should contain the same gradation of materials as those found on the beach to be nourished. Analysis of seven beach samples taken at various points along the Berrien county shoreline show that approximately 99% of the material was retained on the 100 mesh sieve. The optimum fill material should have a median diameter of 0.26 millimeters. The following sources of sand were considered:

(1) Adjoining dunes

A denuded dune area exists about 0.7 mile southwest of the Galien River from which sand could be graded directly onto the beach with dozers and scrapers. This source was not selected because of the high value of beach property near New Buffalo.

(2) Deepening Harbor

Deepening the harbor by an additional six feet over that considered in the report would yield only 48,000 cubic yards, an inadequate amount. With regard to dredge material from new interior lagoons, private interests desire to use the material for land enhancement. The two sources were, therefore, considered to be impracticable.

(3) Lake Michigan

A study showed that suitable sand could be obtained from the lake bottom north of the proposed harbor entrance without harmful effect on beach stability. The estimated cost per cubic yard is $0.65. This cost is based on the use of an 8 inch diameter, 2,000 to 3,000 cubic yard per day hydraulic dredge.

(4) Grand Beach

An analysis of sand in a dune area just north of Grand Beach shows that 99% is suitable beach material. The area is about three miles from the harbor. The cost of hauling sand by truck, spreading and shaping the stockpile is estimated at $2.15 per cubic yard. This source is considered suitable and adequate, but is not recommended because of the high cost. This source has been considered for building protective beaches in the reach from Grand Beach and Michiana Shores, should a project develop.

c. Artificial nourishment

(1) Amount

The deficiency in material supply in the problem shore segment due to the proposed structures is the rate of loss of beach material. This is the rate at which material must be supplied to the transport capacity of littoral forces so that no net loss in littoral drift will occur. During filling of the impounding area this is the full rate of littoral drift or 100,000 cubic yards annually for about 4.6 years and thereafter 10,000 cubic yards annually for 46 years due to the outer harbor dredging. The Galien River borrow material and all dredge spoil will be used for nourishment. Two-thirds of the initial spoil and the borrow material, and about 70 percent of the subsequent dredge spoil is considered suitable beach building material.

(2) Plan

The artificial nourishment plan is shown in table C-2. The plan provides for only two mobilizations of the portable dredge which results in a lowered unit cost of dredging. It furnishes the amounts needed to supply the downdrift shore deficiencies required by the criteria in subparagraph 30c(1). It is assumed that maintenance dredging will be performed at five-year intervals. At the end of the 5th year the total deficiency is estimated to be 460,000 cubic yards plus 10,000 yards of outer channel dredging, or 470,000 cubic yards. The nourishment provided at beginning of the 3rd year will supply the deficiency through the 9th year. At beginning of the 10th year the dredging amounts to 50,000 cubic yards from outer channel for years 5 - 9 inclusive plus 36,000 cubic yards of Galien River material for years 1 - 9 inclusive. For subsequent 5-year dredging of 70,000 cubic yards, 50,000 cubic yards is from outer harbor dredging and 20,000 cubic yards is unsuitable Galien River material from the inner harbor. This plan will restrict erosion to no more than the existing rate, will prevent enlargement of the area now being eroded, and to an indeterminate extent will benefit the entire shoreline in the problem segment.

Table C-2 - Artificial Nourishment Plan

Year	Total deficiency at end of year, 1,000 cu. yds.	Nourishment provided at beginning of year shown, 1,000 cu. yds.				
		Net	Accum. total	Gross	Accum. total	Source
1	100	(30	-	49	-	Initial dredging
		(170	-	251	-	Stockpile
2	200	0	200	0	300	-
3	300	310	510	465	765	Stockpile
4	400	0	510	0	765	-
5	470	0	510	0	765	-
10	520	50	560	86	851	Maintenance dredging
15	570	50	610	70	921	" "
20	620	50	660	70	991	" "
25	670	50	710	70	1061	" "
30	720	50	760	70	1131	" "
35	770	50	810	70	1201	" "
40	820	50	860	70	1271	" "
45	870	50	910	70	1341	" "
50	920	50	960	70	1411	" "

d. Stockpile

(1) Location

The stockpile should be placed so that material will not be carried back to the harbor during westerly storms. The eastern edge of the stockpile will be located about 0.3 mile from the south breakwater, beyond which the erosion is expected to occur. The location is within practical reach of pipelines, and protects the residential area along the shore.

(2) Size

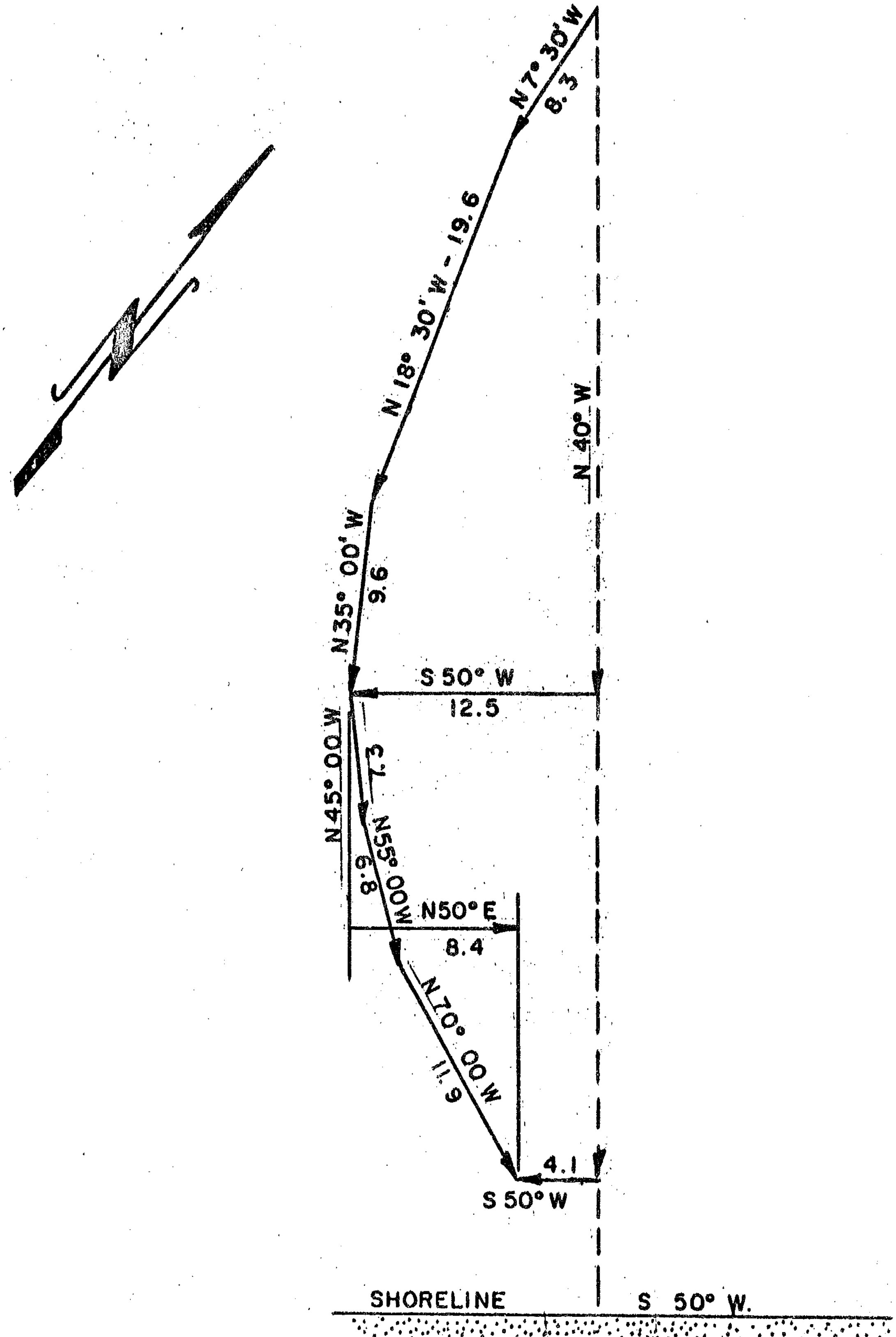
One stockpile is considered adequate. The top elevation of the berm will be 10 feet above LWD or about 2 feet above the natural beach crest elevation. The existing beach is about 150 feet wide and has a slope of about 1:20 at the stockpile location. The berm width should be sufficient to provide for expected recession during the intervals between artificial replenishment. The toe of the stockpile should not extend beyond the 12-foot depth since this would cut off the movement of large amounts of littoral material. The initial fill slope should be parallel to the local beach slope above LWD and from 1:20 to 1:30 below LWD to intersection with the bottom. Stockpile lengths from a few hundred feet to a mile have been successful. Using a berm width of 300 feet and slopes of 1:20 above and below LWD a typical fill section extends to about -8 LWD and provides an area of about 600 square yards. The length of stockpile is 500 yards.

(3) Placing material

The filling will start at +10 feet LWD at the beach crest and progress shorewards to provide 600 square yards fill area without grading to the 1:20 slope. Grading to +10 feet LWD should be done with a dozer. Maintenance spoil would be placed in the same manner. Provision of nourishment material from dredge spoil may cause temporary pollution of the beach. Health authorities have agreed however, in similar cases, that temporary beach closures for several days or so after pumping would reduce this hazard.

31. EVALUATION

The plan of nourishment is based on an assumed rate of littoral drift, volume of impounding area, and the assumption that the littoral material will again reach the downdrift shore after the impounding area has filled. To evaluate the effectiveness of the methods and techniques of the plan it is recommended that periodic shoreline surveys be made subsequent to construction. These surveys would be the basis for volumetric studies which would show if revisions in the assumed plan of nourishment are needed for greater effectiveness.



SCALE:
1" = 8.0 X 10^8 FT. LBS. PER FT. OF WAVE CREST PER YEAR.

FIGURE I

VECTOR DIAGRAM OF ANNUAL WAVE ENERGY AT NEW BUFFALO HARBOR, MICH.

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

APPENDIX D - CORRESPONDENCE

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Letters to the District Engineer dated:	From	Subject
24 January 1961	Michigan State Waterways Commission	Assurances of local cooperation.
25 January 1961	Fish and Wildlife Service, Dept. of Interior	Views on effect of recommended improvement on fish and wildlife resources.

S TE OF MICHIGAN

Waterways Commission

JOHN B. SWAINSON, GOVERNOR

1004 CADILLAC SQUARE BUILDING
DETROIT 26, MICHIGAN

LEONARD H. THOMSON
DETROIT

HAROLD F. FINAN
PORT AUSTIN

DR. WALLACE S. WILLMAN
TRAVERSE CITY

LOUIS H. FREYE
ROMEO

ALBERT B. GREGORY
DETROIT

KEITH WILSON, DIRECTOR

October 24, 1961

Serial No. 1268-61
File No. NBu-C

Clifford S. Ott, Lt. Colonel
Corps of Engineers
Executive Office, Chicago District
536 S. Clark Street
Chicago 5, Illinois

Dear Colonel Ott:

This is in reference to your letter of August 4, 1961, requesting assurances for an additional item of local cooperation covering remedial measures for shoreline erosion to the south of the proposed harbor at New Buffalo, Michigan.

A review of this requirement indicates to this agency that it is already covered by the general assurance that all lands, easements, and rights-of-way necessary for the project be provided by local interests. Therefore, we are of the opinion that no separate and additional assurance of this specific nature is required at this time.

When specific assurances are requested for this project, it would be possible to provide a separate item covering this contingency if you deem it necessary. Otherwise, we are taking the position that the assurance requested has already been provided in our letter of January 24, 1961.

Sincerely yours,

Keith Wilson
Director

KW/v

State Waterways Commission

KEITH WILSON, DIRECTOR
PHONE WOODWARD 1-1024

1004 CADILLAC SQUARE BUILDING
DETROIT 26, MICHIGAN

January 24, 1961

Serial No. 74-61
File No. NBu-C

Clifford S. Ott
Lt. Colonel, Corps of Engineers
Acting District Engineer,
Chicago District
536 South Clark Street
Chicago 5, Illinois

Dear Colonel Ott:

This is in answer to your letter of 11 January 1961, forwarding preliminary prints of the plan of improvement for the New Buffalo Harbor, Michigan, and outlining the terms of local cooperation for this project.

The Michigan State Waterways Commission, by virtue of Act 320 of the Public Acts of 1947, is vested with the authority to enter into agreements with the Federal Government to take advantage of any Congressional Act which provides for navigational benefits in this state. In addition, we are specifically authorized to transmit local assurances on navigational projects and annually collect taxes from recreational boatmen for the purpose of providing local contributions toward such projects, among other things.

The Commission has sufficient funds to be able to assume the financial obligation of local interests for this project. However, standard Commission policy requires that all other assurances be provided by the appropriate political subdivision involved. Although formal provision of these assurances has not as yet been made by the township, present indications are there will be no difficulty in securing these assurances. We are therefore confident that all local assurances, including the cash contribution, will be ready well in advance to the commencement of the final plans for this project.

Sincerely yours,

Keith Wilson
Director

KW:rmr

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
1006 WEST LAKE STREET
MINNEAPOLIS 8, MINNESOTA

NORTH CENTRAL REGION
(REGION 3)
ILLINOIS
INDIANA
IOWA
MICHIGAN
MINNESOTA
MISSOURI
NEBRASKA
NORTH DAKOTA
OHIO
SOUTH DAKOTA
WISCONSIN

ADDRESS ONLY THE
REGIONAL DIRECTOR

January 25, 1961

Refer to: RB

District Engineer
U. S. Army Engineer District
Chicago
536 So. Clark Street
Chicago 5, Illinois

Dear Sir:

The preliminary plan of improvement for New Buffalo Harbor, Michigan enclosed with Mr. R. F. Leeper's letter of January 10, 1961, File No. NCWED-R, has been reviewed by personnel familiar with the area and with personnel of the Michigan Conservation Department.

It was concluded that dredging a channel ten feet deep in Lake Michigan and eight feet deep landward with the spoil deposited in the Village Park area will in no way seriously affect the fish and wildlife resources of the area or affect the commercial and sport fishery of this part of Lake Michigan.

If further modifications are considered, especially any changes that may concern relocation of the dredge-spoil, we would appreciate being advised, so that if necessary these comments may be revised.

Thank you for the opportunity to present our views on this preliminary plan.

Sincerely yours,

W. A. Elkins
Acting Regional Director

U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

ATTACHMENT 1

TO

REVIEW REPORT ON

NEW BUFFALO HARBOR, MICHIGAN

Information called for by
Senate Resolution 148, 85th Congress
adopted 28 January 1958

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U. S. ARMY ENGINEER DISTRICT, CHICAGO
CORPS OF ENGINEERS
536 SOUTH CLARK STREET
CHICAGO 5, ILLINOIS

REVIEW REPORT ON NEW BUFFALO HARBOR, MICHIGAN

Information called for by
Senate Resolution 148, 85th Congress,
adopted 28 January 1958

1. GENERAL

Senate Resolution 148 calls for data in addition to that now presented in support of projects recommended for authorization, and on possible alternatives thereto. Emphasis is given to reasons why alternatives are rejected in favor of recommended projects, and the effects of alternative standards of evaluation, economic analysis, and cost allocation, on project feasibility, scope, and cost sharing arrangements.

2. EXISTING PROJECT

The original Federal project at New Buffalo Harbor has been inactive since 1885. It provided for a channel 12 feet deep through the sand hills between Lake Michigan and the Lake Pottawatomie marshes at the village of New Buffalo. The partially completed project substantially formed the present mouth of the Galien River. Local interests request dredging of an entrance channel 12 feet deep in the lake and an inner channel 10 feet deep in the Galien River, and construction of protective structures at the entrance.

3. COMMERCE

Commercial traffic at New Buffalo Harbor consists of a local catch of fish presently averaging about one ton annually. Locally based and transient recreational boats make numerous trips into and out of the harbor during the pleasure boating season (April through October). Improvement of New Buffalo Harbor to provide safe channels of adequate depth would result in a larger catch of fish, and an increase in the number of local and transient pleasure boats using the harbor.

4. RECOMMENDED IMPROVEMENT

The recommended improvement of New Buffalo Harbor provides for protective breakwaters, an entrance channel 80 to 180 feet wide and 10 feet deep in the lake, and an inner channel 80 feet wide and 8 feet deep in the Galien River. The total estimated first cost of the recommended project is $1,323,000, including costs of $15,000 for the preauthorization study and $5,000 for the required aids to navigation. Average annual charges, based on an economic life of 50 years and an interest rate of 2-5/8 percent on Federal expenditures and 3-1/2 percent on non-Federal public expenditures, are established at $75,000 (including annual maintenance).

5. ECONOMIC ANALYSIS

Benefits expected to result from the recommended project are estimated at $104,000 annually, through gains in recreational value to owners of local and transient pleasure boats at New Buffalo Harbor, reduced damages to light-draft boats, reduced maintenance costs to local interests, and increased commercial fish catch. A comparison of benefits and costs for the improvement results in a favorable ratio of $104,000 to $75,000 or 1.4 to 1.

6. APPORTIONMENT OF COSTS

Benefits accruing to the recommended project are determined to be 48 percent local in nature and 52 percent general. An equitable apportionment of first costs between interests would be on that basis, as follows (August 1961 price levels):

Federal:	
General navigation facilities (52%)	$ 667,000
Preauthorization study	15,000
Required aids to navigation	5,000
Total Federal first cost	687,000
Non-Federal:	
General navigation facilities, cash contribution (48%)	615,000
Lands and rights-of-way	21,000
Total non-Federal first cost	636,000
Total project first cost	1,323,000

Apportioned annual charges are $47,000 Federal (including annual maintenance) and $28,000 non-Federal; total annual charges are $75,000.

7. ALTERNATIVES

Economic analysis on the basis of an economic life significantly greater than 50 years would be highly conjectural because of the difficulties involved in long-range projection of the pattern of recreational usage. There is also little likelihood that the economic life of recreational navigation facilities would exceed 50 years. The recommended improvement will not preclude future enlargement or extension of the project if needed.

8. OTHER REQUESTED IMPROVEMENTS

It was found that a safe draft for the prospective vessel traffic would be afforded by lesser channel depths than requested, and that no additional benefits would accrue to the greater depths. Therefore, the requested channel depths of 10 feet and 12 feet were not considered for the recommended plan of improvement. There is no other practicable alternative to the recommended plan.